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# FACTORS CONCERNED IN THE CONTROL OF VASCULAR PATTERN IN THE INDUCED ROOTS OF ISOLATED LEAVES

By B. Samantarai and S. K. Sinha

*Ravenshaw College, Cuttack-3, India*

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## Introduction

The vascular pattern in adventitious roots is known to be very much variable. Roots arising from the plants of the same species, or from any individual plant or from a single node of a plant show varying number of vascular strands. According to the "Size factor" hypothesis of Bower (1930) the pattern is correlated with the thickness of the roots. Investigations of Torrey (1955), however, indicate that the pattern is determined by the thickness of the promeristem at the level of pattern formation rather than the thickness of the mature root. In any case nothing is known for certain as to the exact nature of factors controlling the variation of vascular pattern. It has been found out (Sinha, 1956) that the adventitious roots induced in isolated leaves by the application of synthetic hormones possess a good deal of variability as to the number of vascular strands in them. Taking advantage of this phenomenon in isolated leaves, an attempt is made here to ascertain the factors concerned in the control of vascular pattern in roots.

## Materials and Methods

Isolated leaves of three different species, *viz.*, *Ipomœa batatas* Lamk., *Impatiens balsamina* L. and *Dædalacanthus splendens* L. were employed in this investigation.

As the formation of roots in isolated leaves is dependent on a supply of root-forming substance and food-material (Gregory and Samantarai, 1950) it was thought that these factors might be in some way responsible for the determination of the vascular pattern.

$\beta$-Indolyl butyric acid (I.B.A.) was used as the root-forming substance. Maleic hydrazide (MH) was used to counteract the action of the native auxin so as to lower the auxin-level. The nutritional factors were controlled by a supply of sucrose and $(NH_4)_2 SO_4$ or starving the

leaves for different periods. Leaves of almost the same age of a particular species were used for all the treatments. Selection of leaves were made from the 8th or the 9th node in case of *Ipomœa*, 5th or 6th node in case of *Impatiens* and from the 3rd node in *Dædalacanthus*.

Groups of leaves of the species mentioned earlier were treated with aqueous solution of I.B.A. at strengths of 2·5, 5, 10 and 25 parts per million (p.p.m.) separately. Similarly other groups were treated with aqueous solutions of MH of the strengths as those of I.B.A. The controls were kept in water. Twenty replicates were taken for each treatment.

Leaves of the same species were also fed with 1% and 2% sucrose solutions and 0·1% and 0·25% of $(NH_4)_2 SO_4$ solutions separately with 20 replicates for each treatment and with equal number of controls. In order to lower down the food supply leaves of all these species were starved for various periods up to 4 days.

To find out the combined effect of hormone and food supply, either freshly isolated leaves or starved leaves, as the case may be, were treated with 5 p.p.m. of I.B.A. Excepting the starved leaves thus treated all other leaves were fed separately with sucrose and $(NH_4)_2 SO_4$ solutions at the strengths given above, at 3-day intervals till the time of root emergence. In all these treatments 20 replicates were taken for each with equal number of controls.

The various details regarding the application of hormone, feeding and subsequent cultural procedure were as suggested by Gregory and Samantarai (1950).

Observations were recorded a week after root-emergence under each kind of treatment as to the number of protoxylem poles (*i.e.*, the number of vascular strands). Sections were taken at the base of roots, except in one experiment, which was meant to determine the variation at different levels of the roots of *Impatiens*, which gradually became tapering towards the tip. The total number of roots with a particular vascular pattern was counted for each kind of treatment and the average number of strands per root was determined.

## Experimental Results

*Effect of I.B.A.*—The effect of I.B.A. on the vascular pattern of the induced roots has been shown in Table I. The data indicate that roots in the leaves of *Ipomœa* without I.B.A. are quite simple in their stelar pattern, being tetrarch, pentarch or hexarch. Treatment with 2·5 p.p.m. of I.B.A. causes the formation of some septarch roots, besides those with simpler pattern. With higher concentration of I.B.A. the pattern becomes more complex in a greater number of roots. Quite an appreciable number of roots induced with 25 p.p.m. of I.B.A. possesses 10 or more vascular strands.

In *Impatiens*, roots in control leaves are much simpler than those of *Ipomœa*, being triarch or tetrarch, even diarch in some cases. I.B.A.

at 2·5 p.p.m. produces roots, many of which are more complex being pentarch and hexarch. The percentage of such pentarch or hexarch or still more complex roots gradually increases along with the rise in the concentration of I.B.A. Roots induced with 25 p.p.m. are found to possess even 10 or more strands. At higher concentrations the degree of complexity is not only great, but also the range of variation of the pattern is wide. At 25 p.p.m. the number of strands varies between 3 and 10 or more.

TABLE I

*Showing the effect of I.B.A. on the vascular pattern of roots of isolated leaves of* Ipomœa, Impatiens *and* Dædalacanthus
(Average of 20 leaves)

| | Concn. of I.B.A. in p.p.m. | Frequency of roots with a particular vascular pattern | | | | | | | | | | Average No. of strands per root | Total No. of roots |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2-arch | 3-arch | 4-arch | 5-arch | 6-arch | 7-arch | 8-arch | 9-arch | 10-arch | >10 arch | | |
| *Ipomœa* | 0 (control) | .. | .. | 9 | 7 | 4 | .. | .. | .. | .. | .. | 4·75 | 20 |
| | 2·5 | .. | 14 | 51 | 58 | 29 | 11 | .. | .. | .. | .. | 4·9 | 163 |
| | 5 | .. | 14 | 36 | 60 | 24 | 15 | 9 | 5 | 3 | .. | 5·3 | 166 |
| | 10 | .. | .. | 32 | 53 | 25 | 17 | 13 | 8 | 9 | .. | 5·9 | 157 |
| | 25 | .. | .. | 26 | 44 | 19 | 14 | 11 | 9 | 7 | 9 | 6·3 | 139 |
| *Impatiens* | 0 | 2 | 12 | 8 | .. | .. | .. | .. | .. | .. | .. | 3·3 | 22 |
| | 2·5 | 2 | 9 | 14 | 12 | 11 | .. | .. | .. | .. | .. | 4·4 | 48 |
| | 5 | 1 | 6 | 12 | 13 | 28 | 4 | .. | .. | .. | .. | 5·1 | 64 |
| | 10 | .. | 5 | 7 | 17 | 27 | 29 | 4 | 2 | 2 | .. | 6·0 | 93 |
| | 25 | .. | 4 | 4 | 32 | 24 | 16 | 4 | 1 | 5 | 5 | 6·2 | 95 |
| *Dædalacanthus* | 0 | .. | .. | .. | 12 | 16 | 12 | .. | .. | .. | .. | 6·0 | 40 |
| | 2·5 | .. | .. | .. | 4 | 5 | 17 | 15 | 3 | .. | .. | 7·3 | 44 |
| | 5 | .. | .. | .. | .. | 7 | 9 | 15 | 13 | 3 | 1 | 8·0 | 48 |
| | 10 | .. | .. | 3 | 23 | 35 | 9 | 13 | 4 | 8 | 4 | 6·7 | 99 |
| | 25 | .. | .. | .. | 27 | 37 | 17 | 8 | 12 | 4 | 4 | 6·7 | 109 |

In the remaining species, *i.e.*, *Dædalacanthus*, the roots of the control leaves are mostly hexarch though some are pentarch or heptarch. Roots induced with 2·5 p.p.m. are mostly septarch or octarch. Only a very few are less or more complex. At 5 p.p.m. more than half of the roots

have 8 or 9 strands, and a good many with even more. At 10 and 25 p.p.m., however, the roots become more widely variable in their pattern, the number of strands ranging between 4 or 5 and 10 or more.

*Effect of MH.*—Treatment with MH, on the other hand, not only inhibits the formation of roots, but also reduces the number of vascular strands in the emerging roots. This is evident from the data presented in Table II.

TABLE II

*Showing the effect of MH on the vascular pattern of the induced roots of isolated leaves of* Ipomœa, Impatiens *and* Dædalacanthus

(Average of 20 leaves)

| | Concn. of MH in p.p.m. | Frequency of roots with a particular vascular pattern | | | | | | Average No. of strands per root | Total No. of roots |
|---|---|---|---|---|---|---|---|---|---|
| | | 2-arch | 3-arch | 4-arch | 5-arch | 6-arch | 7-arch | | |
| *Ipomœa* | 0 (control) | .. | .. | 7 | 9 | 5 | .. | 4·9 | 21 |
| | 2·5 | .. | 2 | 9 | 3 | .. | .. | 4·1 | 14 |
| | 5 | .. | 3 | 5 | 1 | .. | .. | 3·8 | 9 |
| | 10 | .. | .. | .. | .. | .. | .. | .. | 0 |
| *Impatiens* | 0 (control) | 3 | 13 | 7 | .. | .. | .. | 3·2 | 23 |
| | 2·5 | 6 | 10 | 1 | .. | .. | .. | 2·7 | 17 |
| | 5 | 7 | 2 | .. | .. | .. | .. | 2·2 | 9 |
| | 10 | .. | .. | .. | .. | .. | .. | .. | 0 |
| *Dædalacanthus* | 0 (control) | .. | .. | .. | 12 | 17 | 13 | 6·0 | 42 |
| | 2·5 | .. | .. | .. | 17 | 4 | 3 | 5·4 | 24 |
| | 5 | .. | .. | .. | 13 | 3 | .. | 5·2 | 16 |
| | 10 | .. | .. | .. | .. | .. | .. | .. | 0 |

Thus in *Ipomœa*, the roots in control leaves are tetrarch, pentarch or hexarch, pentarch roots being greatest in number. Treatment with 2·5 p.p.m. of MH, besides reducing the number of roots, causes a reduction in the number of vascular strands, these being 3, 4 or 5 and mostly 4. With still higher concentrations, *i.e.*, with 5 p.p.m. the number of roots further decreases, and along with this the number of pentarch roots suffers diminution, and diarch ones show a corresponding increase. No roots emerge at concentrations higher than 5 p.p.m.

A similar trend in the simplification of the pattern, *i.e.*, a reduction in the number of vascular strands is also seen in the other two species of leaves. As MH reduces the level of auxin, the results obtained by the application of MH may be taken as those induced by a very low concentration of auxin.

*Feeding with sugar.*—The results obtained with feeding of sugar as presented in Table III indicate that in all the species supply of sugar

TABLE III

*Showing the effect of feeding with sucrose on the vascular pattern of roots in the isolated leaves of* Ipomœa, Impatiens *and* Dædalacanthus

(Average of 20 leaves)

| | Nature of feeding | Frequency of roots with a particular pattern | | | | | | | | | | Average No. of strands per root | Total No. of roots |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2-arch | 3-arch | 4-arch | 5-arch | 6-arch | 7-arch | 8-arch | 9-arch | 10-arch | >10 arch | | |
| *Ipomœa* | Control | .. | .. | 9 | 5 | 4 | .. | .. | .. | .. | .. | 4·7 | 18 |
| | 1% Sucrose | .. | .. | 5 | 13 | 6 | 3 | .. | .. | .. | .. | 5·3 | 27 |
| | 2% Sucrose | .. | .. | 3 | 9 | 9 | 3 | 2 | .. | .. | .. | 5·7 | 26 |
| | 5 p.p.m. I.B.A. | .. | .. | 29 | 59 | 31 | 12 | 3 | 1 | 2 | .. | 5·4 | 137 |
| | I.B.A. +1% Sucrose | .. | .. | 19 | 60 | 39 | 31 | 19 | 7 | 9 | .. | 6·2 | 184 |
| | I.B.A. +2% Sucrose | .. | .. | 9 | 39 | 58 | 49 | 23 | 18 | 11 | 5 | 6·8 | 212 |
| *Impatiens* | Control | 3 | 10 | 7 | .. | .. | .. | .. | .. | .. | .. | 3·2 | 20 |
| | 1% Sucrose | 3 | 13 | 8 | 1 | .. | .. | .. | .. | .. | .. | 3·3 | 25 |
| | 2% Sucrose | 2 | 12 | 7 | 2 | .. | .. | .. | .. | .. | .. | 3·5 | 23 |
| | 5 p.p.m. I.B.A. | 1 | 5 | 10 | 11 | 23 | 9 | .. | .. | .. | .. | 5·3 | 59 |
| | I.B.A. +1% Sucrose | .. | 5 | 12 | 15 | 16 | 8 | 7 | 5 | .. | .. | 5·75 | 68 |
| | I.B.A. +2% Sucrose | .. | 3 | 11 | 13 | 17 | 5 | 9 | 4 | 2 | 1 | 6·0 | 65 |
| *Dædalacanthus* | Control | .. | .. | .. | .. | 13 | 18 | 10 | .. | .. | .. | 6·9 | 41 |
| | 1% Sucrose | .. | .. | .. | .. | 9 | 16 | 17 | 4 | .. | .. | 7·3 | 46 |
| | 2% Sucrose | .. | .. | .. | .. | .. | 21 | 20 | 7 | .. | .. | 7·7 | 48 |
| | 5 p.p.m. I.B.A. | .. | .. | .. | .. | 11 | 11 | 15 | 9 | .. | .. | 7·5 | 46 |
| | I.B.A. +1% Sucrose | .. | .. | .. | .. | 5 | 14 | 18 | 11 | 7 | .. | 8·0 | 55 |
| | I.B.A. +2% Sucrose | .. | .. | .. | .. | .. | 13 | 21 | 13 | 9 | 4 | 8·4 | 60 |

brings about an increase in the number of vascular strands, and the higher the concentration the greater is the percentage of roots with increased number of strands. When sugar is supplied in addition to I.B.A. the degree of complexity tends to increase further.

The leaves of *Ipomœa*, fed with 1% sucrose, produce roots with as many as 7 strands with a predominant pentarch pattern in most. When fed with 2% sucrose the pattern becomes octarch in some of the induced roots. The picture is almost similar in *Impatiens* and *Dædalacanthus*.

Further, leaves of *Ipomœa*, treated with 5 p.p.m. of I.B.A., have a great percentage of tetrarch, pentarch and hexarch roots and small percentages of roots with greater number of strands. Feeding with sucrose causes a diminution in the number of roots with tetrarch or pentarch pattern and an increase in the number of those with more complex pattern. Similarly in *Dædalacanthus*, roots produced with I.B.A., possess 6 to 9 strands. Those induced with 2% sucrose in addition to I.B.A. show 7 to 10 strands or more, and hexarch or simpler roots are entirely lacking. The condition in *Impatiens* is also similar.

*Feeding with nitrogen*.—Feeding with nitrogen also helps to enhance the complexity of the stele, whether the leaves are treated with I.B.A. or not. Feeding in addition to hormone treatment renders the roots more widely variable in their pattern and complex to a greater extent than what is obtained with hormone-treatment alone. In case of *Impatiens* and *Ipomœa*, however, with the higher dose of nitrogen, the pattern tends to be a bit simpler than that in the lower dose. In *Dædalacanthus*, similarly, a small percentage of roots is more complex and quite a good percentage of roots is simpler in their pattern. Thus the lower dose of nitrogen is found to increase the complexity of pattern as well as the range of variation. The higher dose, though widening the range of variation, tends to render the pattern simpler at least in some roots. These data are presented in Table IV.

*Starvation*.—The data of the experiments with starved leaves are shown in Table V. While 5 p.p.m. of I.B.A. causes the production of good many roots with complex pattern like heptarch or octarch stele, starvation, besides decreasing the total number of roots, induces greater number of roots with relatively simpler pattern and correspondingly reduces the number of roots with complex pattern. The same is true of the other two species also. The pattern is too much simplified in starved leaves not treated with hormone. Under such conditions, roots fail to emerge if starved for more than 2 days in *Ipomœa* and *Impatiens*. Leaves of *Dædalacanthus* can stand starvation for a slightly longer period; no roots, however, develop when starvation is for 4 days.

*Variation and different levels*.—In *Impatiens*, the gradually tapering roots suggested that the pattern might be variable at different levels of the root. Actual sections taken at different portions of the roots induced with 10 p.p.m. of I.B.A. showed that at least in some roots

TABLE IV

*Showing the effect of feeding with* $(NH_4)_2SO_4$ *on the vascular pattern of induced roots in the isolated leaves of* Ipomœa, Impatiens and Dædalacanthus

(Average of 20 leaves)

| | Nature of feeding | Frequency of roots with particular pattern | | | | | | | | | | Average No. of strands | Total No. of roots |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2-arch | 3-arch | 4-arch | 5-arch | 6-arch | 7-arch | 8-arch | 9-arch | 10-arch | >10 arch | | |
| *Ipomœa* | Control | .. | .. | 9 | 5 | 4 | .. | .. | .. | .. | .. | 4·7 | 18 |
| | 0·1% $(NH_4)_2SO_4$ | .. | 1 | 7 | 13 | 9 | 4 | .. | .. | .. | .. | 5·3 | 34 |
| | 0·25% $(NH_4)_2SO_4$ | .. | .. | 6 | 17 | 8 | 1 | .. | .. | .. | .. | 5·1 | 32 |
| | 5 p.p.m. I.B.A. | .. | .. | 29 | 59 | 31 | 12 | 3 | 1 | 2 | .. | 5·4 | 137 |
| | I.B.A.+ 0·1% $(NH_4)_2SO_4$ | .. | .. | 17 | 33 | 63 | 27 | 7 | 3 | 9 | .. | 6·1 | 159 |
| | I.B.A.+ 0·25% $(NH_4)_2SO_4$ | .. | .. | 23 | 31 | 71 | 43 | 15 | 9 | .. | .. | 6·1 | 192 |
| *Impatiens* | Control | 3 | 10 | 7 | .. | .. | .. | .. | .. | .. | .. | 3·2 | 20 |
| | 0·1% $(NH_4)_2SO_4$ | 5 | 13 | 11 | 4 | .. | .. | .. | .. | .. | .. | 3·4 | 33 |
| | 0·25% $(NH_4)_2SO_4$ | 4 | 15 | 10 | 1 | .. | .. | .. | .. | .. | .. | 4·3 | 30 |
| | 5 p.p.m. I.B.A. | 1 | 5 | 10 | 11 | 23 | 9 | .. | .. | .. | .. | 5·3 | 59 |
| | I.B.A.+ 0·1% $(NH_4)_2SO_4$ | 3 | 9 | 11 | 17 | 19 | 7 | 5 | 4 | 2 | .. | 5·5 | 77 |
| | I.B.A.+ 0·25% $(NH_4)_2SO_4$ | 4 | 11 | 13 | 16 | 17 | 8 | 3 | .. | .. | .. | 5·0 | 72 |
| *Dædalacanthus* | Control | .. | .. | .. | .. | 13 | 18 | 10 | .. | .. | .. | 7·0 | 41 |
| | 0·1% $(NH_4)_2SO_4$ | .. | .. | .. | .. | 15 | 14 | 13 | 8 | .. | .. | 7·3 | 50 |
| | 0·25% $(NH_4)_2SO_4$ | .. | .. | .. | .. | 10 | 18 | 16 | 7 | .. | .. | 7·4 | 51 |
| | 5 p.p.m. I.B.A. | .. | .. | .. | .. | 11 | 11 | 15 | 9 | .. | .. | 7·4 | 46 |
| | I.B.A.+ 0·1% $(NH_4)_2SO_4$ | .. | .. | .. | .. | 10 | 17 | 16 | 12 | 8 | .. | 7·9 | 63 |
| | I.B.A.+ 0·25% $(NH_4)_2SO_4$ | .. | .. | .. | 4 | 11 | 15 | 15 | 10 | 6 | 2 | 7·7 | 63 |

TABLE V

*Showing the effect of starvation on the vascular pattern of roots in the isolated leaves of* Ipomœa, Impatiens *and* Dædalacanthus

(Average of 20 leaves)

| | Period of starvation in days | Whether treated with I.B.A. or not | Frequency of roots with a particular pattern | | | | | | | | Average No. of strands per root | Total No. of roots |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2-arch | 3-arch | 4-arch | 5-arch | 6-arch | 7-arch | 8-arch | 9-arch | | |
| *Ipomœa* | 0 | Treated | .. | .. | 27 | 61 | 29 | 13 | 3 | 1 | 5·3 | 134 |
| | 1-day | Treated | .. | .. | 36 | 52 | 29 | 7 | 2 | .. | 5·1 | 126 |
| | 2-days | Treated | .. | 7 | 21 | 41 | 19 | 5 | 3 | .. | 5·0 | 96 |
| | 3-days | Treated | .. | 11 | 23 | 29 | 11 | 2 | .. | .. | 4·6 | 76 |
| | 4-days | Treated | 2 | 13 | 18 | 5 | 3 | .. | .. | .. | 3·9 | 41 |
| | 0 | Not treated | .. | .. | 10 | 7 | 3 | .. | .. | .. | 4·65 | 20 |
| | 1-day | Not treated | .. | 5 | 7 | 3 | .. | .. | .. | .. | 3·9 | 15 |
| | 2-days | Not treated | .. | 3 | 2 | .. | .. | .. | .. | .. | 3·4 | 5 |
| *Impatiens* | 0 | Treated | .. | 7 | 11 | 13 | 12 | 5 | .. | .. | 4·9 | 48 |
| | 1-day | Treated | 4 | 10 | 7 | 6 | 5 | 1 | .. | .. | 4·0 | 33 |
| | 2-days | Treated | 7 | 9 | 6 | 2 | 1 | .. | .. | .. | 3·2 | 25 |
| | 3-days | Treated | 5 | 8 | 2 | .. | .. | .. | .. | .. | 2·8 | 15 |
| | 4-days | Treated | 4 | 3 | 1 | .. | .. | .. | .. | .. | 2·6 | 8 |
| | 0 | Not treated | 4 | 9 | 5 | .. | .. | .. | .. | .. | 3·0 | 18 |
| | 1-day | Not treated | 5 | 2 | 1 | .. | .. | .. | .. | .. | 2·5 | 8 |
| | 2-days | Not treated | 2 | 1 | .. | .. | .. | . | .. | .. | 2·4 | 3 |
| *Dædalacanthus* | 0 | Treated | .. | .. | .. | .. | 7 | 9 | 17 | 10 | 7·7 | 43 |
| | 1-day | Treated | .. | .. | .. | .. | 8 | 15 | 8 | 1 | 7·0 | 32 |
| | 2-days | Treated | .. | .. | .. | 4 | 11 | 6 | 1 | .. | 6·2 | 22 |
| | 3 days | Treated | .. | .. | .. | 4 | 7 | 2 | .. | .. | 5·8 | 13 |
| | 4-days | Treated | .. | .. | 1 | 4 | 1 | .. | .. | .. | 5·0 | 6 |
| | 0 | Not treated | .. | .. | .. | 11 | 17 | 12 | .. | .. | 6·0 | 40 |
| | 1-day | Not treated | .. | .. | .. | 15 | 8 | 3 | .. | .. | 5·5 | 26 |
| | 2-days | Not treated | .. | . | 4 | 9 | 2 | .. | .. | .. | 4·9 | 15 |
| | 3-days | Not treated | .. | .. | 5 | 1 | .. | .. | .. | .. | 4·2 | 6 |

the pattern becomes simpler towards the apical region of roots. This is shown by the data presented in Table VI.

TABLE VI

*Showing the variation of the pattern at different levels of the roots of* Impatiens balsamina

(In a total of 93 roots)

| Level of section | Frequency of vascular pattern | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 3-arch | 4-arch | 5-arch | 6-arch | 7-arch | 8-arch | 9-arch | 10-arch |
| Base .. | 5 | 7 | 17 | 27 | 29 | 4 | 2 | 2 |
| Middle .. | 5 | 9 | 22 | 25 | 28 | 4 | .. | .. |
| Apex .. | 8 | 9 | 22 | 25 | 27 | 2 | .. | .. |

## DISCUSSION

On an examination of the results, two aspects regarding the variation of vascular pattern in the induced roots become conspicuous, *viz.*, (1) the degree of complexity of the pattern and (2) the range of variation of the pattern.

The results reveal that the complexity of the pattern increases with the application of I.B.A. whereas MH reduces it. I.B.A. is regarded as a hormone and MH as an antihormone. The action of a hormone is to activate cell-division. Therefore, under the action of I.B.A. there is every probability of the formation of a large number of cells resulting in the complexity of the pattern. Another role of hormone is to bring about hydrolysis of food products directing the course of translocation of these products to the region of cell-division (Gregory and Samantarai, 1950). Therefore, hormone is responsible in increasing the complexity in two ways, *viz.*, (*a*) by initiating cell-division and (*b*) by supplying nutrition to the dividing region. That the supply of food hydrolysed and translocated by hormones increases complexity is seen from the enhancing action of sugars and nitrogen supplied as feeding material separately and along with I.B.A. on the complexity of the pattern. The presence of MH has no action in promoting cell-division and moreover, it probably renders the native auxin ineffective in some way or other, so that the simplification of the pattern becomes distinct. It has been said that along with hormone, the food-factor has much to do with the complexity and this is further corroborated by the effect of starvation on the pattern. The pattern becomes very simple. Torrey (1955) working on the isolated pea-roots holds a similar view to some extent when he concludes that 'pattern-formation is governed by those factors which influence cell division and cell elongation in the apical meristem'.

As to the range of variation of the pattern, it is seen that with I.B.A. and food supply the range becomes wide. The first-formed roots are more complex showing the enhancing action of hormone and food-stuff, whereas the later formed roots are simpler showing the effect of a diminished quantity of hormone and food supply. Therefore, there is a wider range of variation under these conditions. Likewise, observations regarding the gradual decrease in complexity with distance from the base of the root are explicable in terms of gradually diminishing food supply. It seems that the auxin and food supply determine the vascular pattern in the induced roots of isolated leaves to a very great extent.

## SUMMARY

It is very usual that the vascular pattern in the adventitious roots is very much variable in a plant. In order to ascertain the factors that control the variation in the adventitious roots, investigations were made in the induced roots in isolated leaves of *Ipomœa batatas* Lamk., *Impatiens balsamina* L. and *Dædalacanthus splendens* L. The leaves were subjected to the following treatments, before induction of roots:—

(1) The leaves were treated with aqueous solution of β-indolyl butyric acid (I.B.A.) at 2·5, 5, 10 and 25 parts per million (p.p.m.).

(2) Treatment with maleic hydrazide (MH) was given with the same concentrations given for I.B.A.

(3) They were fed with different doses of sucrose and $(NH_4)_2 SO_4$ for supplying sugar and nitrogen respectively.

(4) In addition to the hormone treatment at 5 p.p.m. the leaves were also fed with sucrose and $(NH_4)_2 SO_4$ solutions.

(5) Some other leaves were subjected to starvation for varying periods prior to treatment with I.B.A.

The vascular pattern of the adventitious roots under these conditions was as follows:—

(1) Roots induced by I.B.A. showed a higher number of vascular strands than the roots in the control leaves. The number increased along with the rise in concentration.

(2) Roots induced after treatment with MH showed a reduced number of strands compared with those in the control leaves.

(3) Roots arising after sugar and nitrogen feeding also possessed a greater number of strands than the control ones.

(4) Supply of sugar or nitrogen in addition to treatment with I.B.A. induced a greater number of roots with a higher number of strands than those induced by hormone alone. Sugar was, however, more effective in this respect than nitrogen.

(5) Starving the leaves prior to treatment with I.B.A. caused the production of roots with a smaller number of strands.

It is, therefore, concluded that hormone and food, especially sugar, are chiefly responsible for the control of vascular pattern in the adventitious roots of isolated leaves.

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# OBSERVATIONS ON THE ANATOMY, CYTOLOGY, DEVELOPMENT OF THE REPRODUCTIVE STRUCTURES, FERTILIZATION AND EMBRYOLOGY OF *PELVETIA CANALICULATA* DCNE. *ET* THUR.[1]

## Part II. Development of the Conceptacles, Reproductive Structures and Meiotic Division of the Nucleus during Gametogenesis[2]

By R. Subrahmanyan

*Central Marine Fisheries Research Station, Calicut-5, South India*

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### Introduction

Bower (1880) appears to be the first person to describe the development of the conceptacle in the Fucales. He investigated *Fucus serratus* in detail and *F. platycarpus*, *F. spiralis*, *F. vesiculosus*, *Ozothalia nodosa* (*Ascophyllum nodosum*), *Halidrys siliquosa* and *Himanthalia lorea* in a supplementary way. He showed that each conceptacle originated from a single cell in all these forms. Oltmanns (1889) investigated in detail *Ascophyllum nodosum*, *Halidrys siliquosa* and *Himanthalia lorea* and gave some particulars relating to a species of *Fucus* also. He states that he could not investigate the development of the conceptacle in *Pelvetia* as only ripe material was available to him. Nienburg's (1913) investigations on *Himanthalia*, *Fucus*, *Ascophyllum*, *Pelvetia fastigiata*, *Cystoseira*, *Halidrys*, *Sargassum* and *Pycnophycus* were very thorough.[3] A single initial cell gave rise to the conceptacle in all these forms, though there are differences in the mode of division of the conceptacle initial. He states (1913, p. 18) that though he obtained material of *Pelvetia canaliculata* at different times from Norway and Plymouth, he could not find any young receptacles and, therefore, finally investigated the American species, *P. fastigiata*, obtained from California. Hence, the investigation of the development of the conceptacle in *Pelvetia canaliculata* was of special interest to the writer. Particulars relating to the material and technique employed have already been described in the first part of this series (Subrahmanyan, 1956).

### Development of the Conceptacle

#### *Early Stages*

During the reproductive season, a large number of the apices of the fronds in *Pelvetia canaliculata* show several flask-shaped depres-

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[2] The First Part appeared in *J. Indian bot. Soc.*, 35: 374–90, 1956.

[3] Roe's (1916) account for *Fucus* is at variance with all the others and, according to Fritsch (1945, p. 363), requires confirmation.

sions, the conceptacles, inside which oogonia and antheridia are produced. The conceptacles are confined to a certain region of the thallus in the apical portion and these portions are termed receptacles (Pl. I, Fig. 6). Only fertile conceptacles are present in this alga.

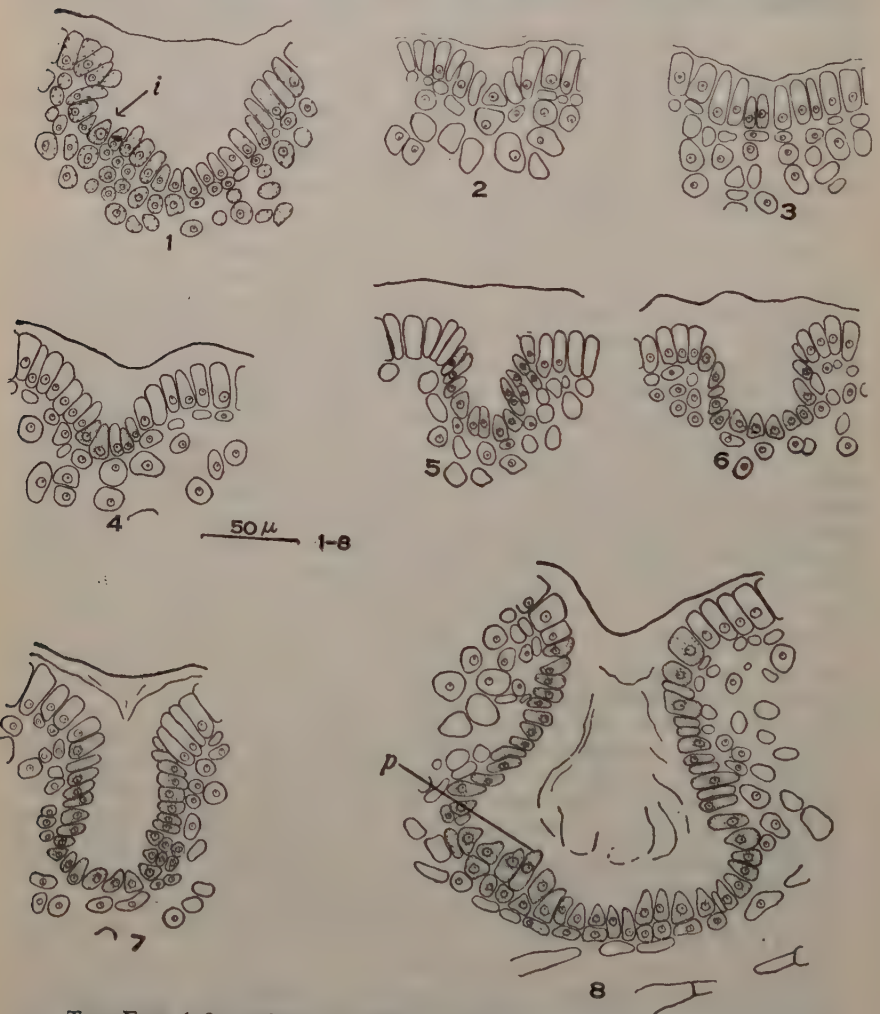
The writer (Subrahmanyan, 1948 *a*) found the earliest stages in the initiation of the conceptacles usually in January, and sometimes a little earlier. The apices of the fronds showing the early stages are very difficult to recognize from the vegetative ones. It was found that a peak in this stage of conceptacle initiation is attained in a short time—in a month or so—and such being the case the development ought to be rapid, so rapid that, later on, all the conceptacles appear to be in the same stage of development. Nienburg (1913, pp. 22–23) also has drawn attention to the rapidity of the development of the conceptacles in the forms investigated by him.

The best sections for the study of the early stages in the development of the conceptacles are median longitudinal sections parallel to the flat surface of the thallus. Text-Fig. 1 shows such a section. The apical cell at the bottom of the furrow appears to be so actively dividing that it is not easily recognizable from the lateral segments. The actively dividing nature of the cells in this region is further shown by the almost complete absence of chromatophores in them. Chromatophores become manifest in the cells a little farther from the apical cell. In Text-Figs. 1 and 2 and Pl. I, Fig. 1, can be seen a cell with a rather prominent nucleus situated between others showing chromatophores, the cells of the meristoderm. This single cell shows no chromotophores and already it is sunk a little owing to the activity of the surrounding cells. This is the conceptacle initial. The initial is somewhat three-sided in sections with rounded corners, the apex directed outwards and the base towards the inside of the thallus.

The conceptacle initial first divides into two by a longitudinal anticlinal wall (Text-Fig. 3). From a large number of sections examined critically, it appears that the subsequent divisions of the two cells and of the daughter cells formed by them are all in the anticlinal plane (Text-Figs. 4 and 6) so that the cavity of the future conceptacle rapidly increases. These cells formed as a result of this activity originated by the conceptacle initial, appear as if they are a continuation of the meristoderm but stand out clearly from this tissue, as well as the inner cortical elements in that they possess no chromatophores and show a rather more prominent nucleus and dense cytoplasm. They cut off cells towards the base (Text-Figs. 5, 7 and 8) and these, by further divisions, periclinally and anticlinally ultimately form a lining for the conceptacle, three to four, rarely five, layers in thickness. In the meantime, the cavity of the conceptacle appears to become filled gradually with mucilage (Text-Figs. 7 and 8). The neck of the conceptacle becomes narrower owing to the activity of the meristoderm, while the base of the conceptacle widens out by division of the cells forming the lining.

As the tissue of the lining layer develops into a compact layer, three to four cells deep, the uppermost cells begin to produce hairs

or paraphyses (Text-Fig. 8, *p*). The cells of the lining tissue show a distinct nucleus and a number of chromatophores. The paraphyses develop rather fast and are more densely produced in some regions than in others, thus apparently dividing the cavity of the conceptacle into a number of chambers (Pl. I, Fig. 2). The cavity of the conceptacle appears to be completely filled with mucilage. At this stage oogonia




TEXT-FIGS. 1–8. *Pelvetia canaliculata*. Development of the Conceptacle. Fig. 1. L.s. of the apex showing conceptacle initial (*i*) near apical furrow. Fig. 2. Conceptacle initial somewhat sunk in the surface of the thallus. Fig. 3. First division of the conceptacle initial (longitudinal). Figs. 4 and 6. Further divisions of the products of the conceptacle initial leading to the formation of the cavity. Figs. 5 and 7. Beginnings of transverse divisions in the layer of cells to form the lining of the conceptacle. Fig. 8. Lining tissue of the conceptacle developed further; note upper cells elongating to form paraphyses.

begin to make their appearance (Pl. I, Fig. 2, *o*). The antheridia develop a little later. The conceptacle enlarges considerably in size and provides room for the developing reproductive bodies, of which large numbers are produced in each conceptacle.

*Relation of the Conceptacle Initial to the Apical Cell*

There is some evidence in *Pelvetia canaliculata* to show that the conceptacle initials have some relation to the apical cell. Serial sections in a longitudinal plane parallel to the flat surface of the thallus, show young conceptacles alternating one to the left and one to the right of the apical furrow. This appearance is soon lost owing to the swelling of the thallus caused by the profuse development of mucilage inside the receptacle. It is probable that the conceptacle initials represent definite segments of the apical cell cut off in succession and destined for this purpose; otherwise, it is incomprehensible how one particular cell alone of the superficial layer (meristoderm) of cells should appear a little sunken below the general surface level of the thallus. In other words, as Fritsch (1945, p. 365) has stated, the initial cells of the conceptacle may be regarded as equivalents of branch initials, which like the latter become lodged in a depression although diverted to a special purpose. The initials always occur at intervals separated by meristoderm cells. Again, it may be pointed out that the conceptacle initials in some genera (*e.g.*, *Fucus*) are hardly recognizable from the other cells of the meristoderm and in some other genera they have been known to possess some characteristic form (*e.g.*, *Sargassum*). In *Pelvetia canaliculata*, the initial differs from the cells of the meristoderm in being somewhat three-sided in section whereas the cells of the meristoderm are palisade-like cells which fit together.

While the conceptacle initials are being cut off, the apical cell initiates branching of the thallus also. The apical cell of each such branch behaves in the same manner as the parent cell in cutting off conceptacle initials and also frequently initiating a further branching of the thallus. Such behaviour ultimately results in a much-branched receptacle, the conceptacles in them extending down to several forks from the apices of the fronds. This behaviour of the apical cell too indicates that the conceptacle initials are, very probably, predestined segments of the apical cell, and, are homologous to branch initials.

The apical cell, after giving rise to a large number of conceptacle initials, is no longer clearly recognizable at the base of the furrow, which in the meanwhile has been becoming shallower gradually. The furrow finally disappears, the apical cell appears to spend itself out, and a swelling of the thallus in the receptacular region takes place, caused by the production of mucilage and the general increase in the size of the conceptacles themselves.

It may be of interest to mention here some peculiarities observed in the formation of the receptacles, presumably due to the eccentric behaviour of the apical cell. Subrahmanyan (1948 *a*, unpublished) observed in this alga, during the reproductive period, a few plants having

stray conceptacles far below the usual receptacular ends; in fact, separated by a gap of vegetative tissue which, in one instance, was observed to be nearly as large as 2 cm. The conceptacles in them were perfectly normal ones. This condition is probably due to the fact that, after a few conceptacles had been initiated, a little vegetative growth intervened before the initiation of conceptacles was resumed again by the apical cell. Lami (1938, pp. 180–81, Pl. I, Fig. 1) cites such an instance and states that, after differentiation of an "intercalary receptacle", the extremity grows and produces again at its apical region new receptacles, and in one instance found three such successively. He is inclined to attribute this to an ecological origin. He gives the plant the name *P. canaliculata* f. *interposita* Lami. The author states that this form is not rare in the region of Minho, and Hamel has observed such forms not far from there, in Galice in 1927. The writer has observed only a few plants of *P. canaliculata* very similar to that recorded by Lami, and is inclined to believe that it is only a minor deviation from the normal condition, for, the same plant bearing both the normal as well as "intercalary" receptacles side by side have been met with; in other words, the plants in question did not show these "intercalary" receptacles exclusively on them.

Again, in some instances, a few receptacles were seen which had a strikingly tapering extremity unlike that of the normal receptacles. Sections showed only one or two stray conceptacles in this tapering region and the receptacles were smaller than the usual ones met with, and even these occurred more towards the base of the tapering portion. These types of receptacles also occurred on one and the same plant along with the normal ones. It is possible that here also this peculiarity is brought about by the growth of the apex after giving rise to some conceptacles and the apical cell finally spending itself out. The similarity of these to those found on *P. canaliculata* var. *acutilobata* described by Lami (1938, pp. 180–81, Fig. 2) is worth noting.

### *The Mature Conceptacle*

In a transverse section, a receptacle may appear narrowly elliptical or broadly elliptical or sometimes almost round (Pl. I, Fig. 7). This depends on the quantity of mucilage produced inside the receptacle. The arrangement of the conceptacles in two rows, one row each on the margin of the flat thallus, noticed in the earlier stages, is soon lost. The receptacles show the same anatomical structure as that of the thallus except for the obliteration of the channel by the swelling caused by the enormous production of mucilage and the presence of sunken conceptacles at the periphery. In the mature receptacles, the outermost layer of cells functions only as an epidermis; the cortex is three to four layers thick with cells showing dense contents and thickened walls; and the medullary elements appear to be floating in the mucilaginous matrix. Sometimes, the very centre of the section shows no medullary strands and is occupied wholly by mucilage of a tough consistency. Externally, the colour of the receptacles change from green to yellow and then to orange as they grow older.

The conceptacles in the mature receptacles are flask-shaped, have a lining tissue, three to five cells in thickness, rich in contents, and they open out by means of an ostiole (Pl. I, Figs. 7 and 8). From the lining tissue arise paraphyses, oogonia and antheridia. In *Pelvetia canaliculata* both oogonia and antheridia occur in the same conceptacle; the alga is, therefore, hermaphroditic (Pl. I, Figs. 7 and 8).

Very often, the cortical region of the mature receptacle shows plenty of fungal mycelia traversing the intercellular spaces, and at the margin, in sections, the fruit bodies of the fungus are seen sunk in the tissue of the receptacle. They are more or less flask-shaped like the conceptacles of the host, and have a lining tissue of their own. The fruit body opens out by a small ostiole. Within the fruit body asci with ascospores are seen commonly (Pl. I, Fig. 10). The fungus appears to be a species of *Mycosphærella*. The infestation by the fungus appears to bring about a fall in the number of receptacles which complete the cycle of reproduction (Subrahmanyan, 1948 *a*, unpublished). It may be mentioned here that Sutherland (1915 *a*, *b*) has described several species of fungi parasitising *Pelvetia* and similar records have been made for the other Fucaceæ also (Cotton, 1908; Church, 1893; and Davis, 1943). Externally, the fruit bodies of the fungus appear as tiny black dots on the receptacles.

### *Paraphyses*

Sections of the conceptacles do not give complete demonstration of the paraphyses as they are invariably cut irregularly and individuals cannot be traced, because of their enormous numbers and degree of interlacing which follows as a result. They are seen best when teased out of the conceptacles. The paraphyses do not project beyond the ostiole as they do in *Fucus* (Thuret, 1854). Text-Figs. 31 and 33 show two types of paraphyses, unbranched and branched respectively. The third type had its uppermost cell swollen and it resembled somewhat those observed by Nordhausen (1910) in *Fucus vesiculosus*. The cells of the paraphyses show a nucleus and varying number of chromatophores. Sometimes two globular bodies (?) are seen, one situated on either side of the nucleus. The cells have dense cytoplasmic contents. The swollen paraphyses suggest a glandular rôle for them and presumably they secrete the mucilage found inside the conceptacle (Nordhausen, 1910, p. 291).

## Development of the Reproductive Bodies

### *The Oogonia*

The oogonium precedes the antheridium in the order of appearance. It arises from the lining of the conceptacle. The earliest stage seen is shown in Pl. I, Fig. 2. The cell of the lining layer after cutting off an oogonium rudiment, often undergoes one or two anticlinal divisions. The presence of a definite stalk cell could not be established. In the American species, *P. fastigiata*, Moore (1918) describes a stalked oogonium. The oogonium stains rather darkly and this makes the

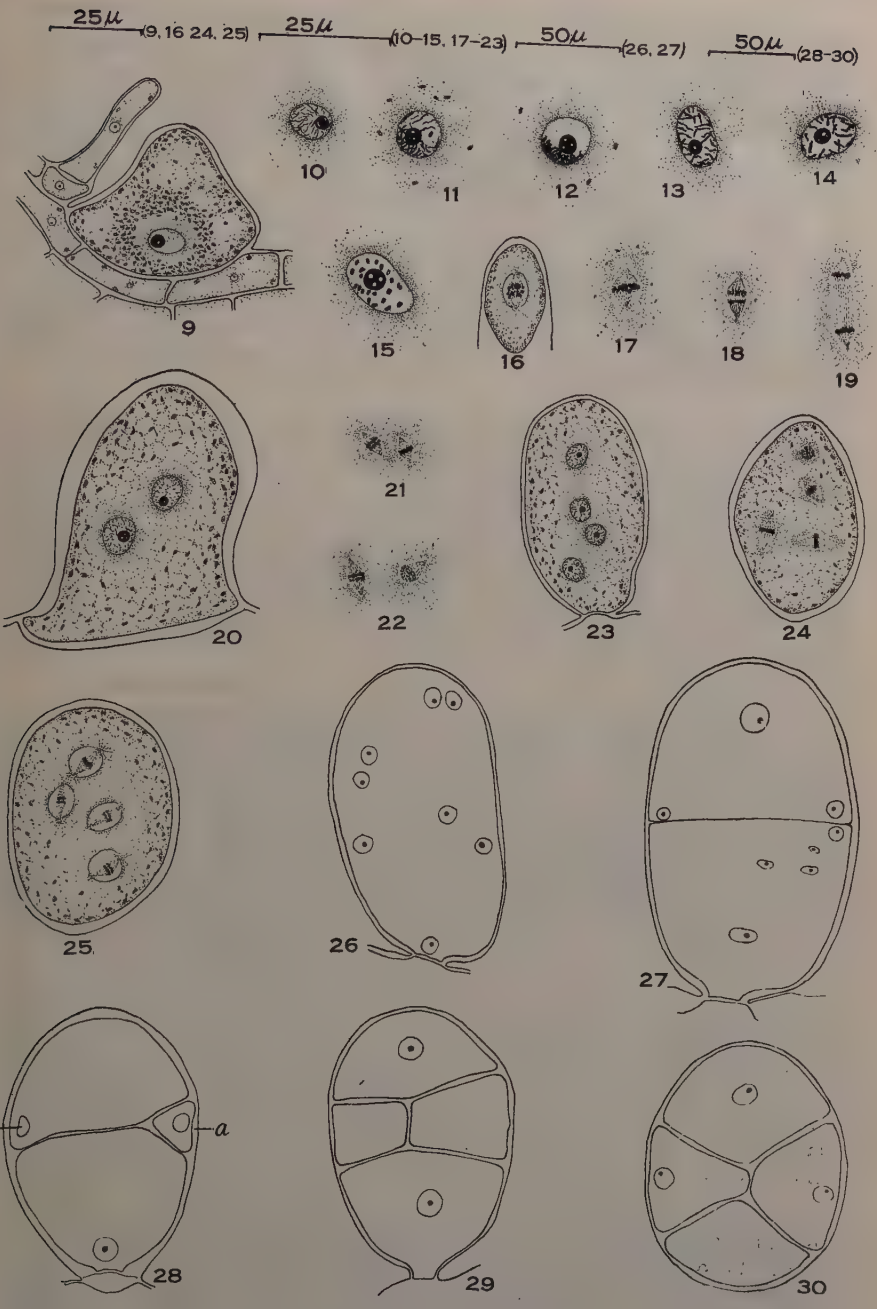
nuclear changes difficult to be followed but a study of a large number of sections furnished the details. The nucleus is seen situated often towards the base of the oogonium surrounded by a dense aggregation of cytoplasm. Large numbers of chromatophores and darkly stained granules are present in its cytoplasm and these are seen arranged in a ring around the nucleus, at a short distance from it (Text-Fig. 9). The nucleus, during the maturation division of the oogonium, divides thrice, the first division constituting the characteristic meiosis.

The resting nucleus shows a clear nuclear membrane, and a very prominent nucleolus which is sometimes vacuolated. Frequently, a second smaller nucleolus-like body is present. The reticulum is very lightly stained (Text-Fig. 9).

During prophase, the nucleus increases in volume and a large number of long, thin, thread-like chromosomes become evident in the nuclear cavity (Text-Fig. 10). In the next stage observed, all the chromosome threads, or most of them, are seen lying compactly in a mass adpressed on one side of the nuclear membrane (Synizesis stage, Text-Figs. 11 and 12). Several individual threads of chromosomes could still be followed in this compact mass which appears to consist of chromosomes forming loops. In one instance, a small, short, darkly stained body was observed in the clear space inside the nuclear cavity, not unlike that occasionally seen in the resting nucleus (Text-Fig. 11). The nature of this body could not be determined. Yamanouchi (1909) has observed in *Fucus vesiculosus* the looped appearance of the chromosomes at synizesis and also a dark body similar to the one noticed here.

The chromosome threads next appear to thicken and shorten and are seen distributed more or less uniformly within the nuclear cavity (Text-Fig. 13). The chromosomes become further thickened and shortened and close examination reveals their paired nature (Text-Fig. 14). In diakinesis, a large number of bivalents, short and darkly stained, are seen distributed inside the nuclear cavity (Text-Fig. 15). An accurate estimation of their number was difficult; however, about 22 (*n*) bivalents could be counted.

The bivalents next orient themselves at the centre of the nuclear cavity (Text-Fig. 16). At this stage, the nucleolus is not evident though the nuclear membrane is still present; at the poles, however, it is not quite visible. The spindle appears at about this stage; it is intranuclear and its poles correspond to the regions where the nuclear membrane appears to have faded. No centrosomes were recognizable at the poles of the spindle. At metaphase, the bivalents are found arranged in a compact plate at the equator of the spindle (Text-Fig. 17). At this stage, the nuclear membrane has completely disappeared, but the nuclear space still stands out conspicuously. After anaphase (Text-Figs. 18 and 19) and telophase, two daughter nuclei are organized (Text-Fig. 20).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FIGS. 9–30

TEXT-FIGS. 9–30. *Pelvetia canaliculata.* Development of the oogonium. Fig. 9. Oogonium rudiment; nucleus in resting condition. Fig. 10. Early prophase of meiosis in the nucleus of the oogonium rudiment. Figs. 11 and 12. Synizesis; in Fig. 11 note the tiny dark body (?) inside the nuclear cavity. Figs. 13 and 14. Pre-diakinetic stages; bivalents shortened and thickened. Fig. 15. Diakinesis. Fig. 16. Early metaphase; bivalents irregularly arranged at the equator of the spindle; nuclear membrane disappeared only at the poles of the intranuclear spindle. Fig. 17. Metaphase of the I Division. Figs. 18 and 19. Anaphase stages of I Division. Fig. 20. Two-nucleate oogonium. Figs. 21 and 22. II Division of the meiosis in the oogonium. Fig. 23. Four-nucleate oogonium. Figs. 24 and 25. III Division of the nuclei in the oogonium; note in Fig. 25, the nuclear membrane still present (figures reconstituted from four sections). Fig. 26. Eight-nucleate oogonium (figure reconstituted from more than one section). Fig. 27. Protoplast of oogonium divided into two; two normal and six supernumerary degenerating nuclei are seen; in one ovum four degenerating nuclei are seen (occasional instance) (figure reconstituted from more than one section). Fig. 28. Supernumerary nuclei being cut off with cytoplasm. Figs. 29 and 30: Four ova formed inside the oogonium (rare instance).

The two nuclei do not appear to pass into a resting condition, but remain in a prophase stage (Text-Fig. 20). They next undergo the second division (Text-Figs. 21 and 22) and four nuclei are organized (Text-Fig. 23) which also remain in a prophase condition and undergo the third division (Text-Figs. 24 and 25). The intranuclear division figure was very strikingly seen in some instances during this division (Text-Fig. 25). Cytoplasmic radiations were seen sometimes at the poles of the spindle as also a centrosome-like body in one instance during this stage. Eight nuclei ultimately result inside the oogonium (Text-Fig. 26).

Meiotic division of the nucleus, during the development of the oogonium, has been established in some other genera also, *viz.*, *Fucus* (Strasburger, 1897; Yamanouchi, 1909), *Ascophyllum* (Farmer and Williams, 1898), *Cystoseira* (Nienburg, 1910), *Sargassum* (Nienburg, 1910; Kunieda, 1926; Tahara and Shimatomai, 1926; Okabe, 1929), *Cystophyllum* (Shimatomai, 1928) and *Coccophora* (Tahara, 1929). In *Pelvetia wrightii*, Inoh (1935) observed only the second division in the oogonium. The earlier stages in the meiotic division of the nucleus in the oogonium do not appear to have been recorded for any species of *Pelvetia* before.

While the nuclear changes are taking place within it, the oogonium grows considerably in size, and becomes very rich in contents. The base is drawn in narrowly so that it appears as though it has a stalk (Text-Figs. 23 and 26). The wall of the oogonium shows some thickening, but as yet, there is no striking indication of the characteristic differentiation of the layers in the wall, which appears to take place after the contents of the oogonium have divided (Pl. I, Fig. 9).

After the eight-nucleate stage has been attained, the protoplast of the oogonium in *Pelvetia canaliculata* generally divides into two to form the ova. It is very difficult to decide how this division is effected as observations on living material are rendered impossible owing to the position of the oogonia inside the conceptacles. From an examination of a number of preparations, the writer is inclined to believe tha

the division is effected, very probably, by a centripetal cleavage furrow which cuts the contents into two. This division is transverse to the long axis of the oogonium and the protoplast is divided into two equal halves (Text-Fig. 27; Pl. I, Fig. 9). In the oogonium of *Pelvetia canaliculata*, Oltmanns (1889, p. 84) speaks of a thin partition wall between the ova. It is doubtful whether there is such a wall. The two ova lie very closely pressed to each other. Further details regarding the oogonium and its wall will be referred to when dealing with the liberation of the oogonia and fertilization.

In *Pelvetia wrightii*, the division in the oogonium to form two ova takes place longitudinally, *i.e.*, perpendicular to the short axis, or obliquely (Yendo, 1907; Inoh, 1935). A similar condition is described for *P. fastigiata* by Gardner (1910) and Moore (1928); but, Holtz (1903) describes the division as transverse in this alga.

It may be interesting to point out here that in the conceptacle of *Fucus*, according to Oltmanns (1889, p. 74), the division of the contents of the oogonium is not achieved by cell-wall formation, but the contents are differentiated into eight equal parts by a cleavage ("Trennungsfurchen"). Strasburgher (1897, pp. 358–60) and Farmer and Williams (1898, p. 628) on the contrary, observe that division is effected by cell-plate formation. These observations point to the necessity for a detailed investigation of cell division and cell-wall formation in the Fucales.

Normally, each daughter protoplast in *P. canaliculata* shows four nuclei. Already in this stage, three of the nuclei in each are very much shrunken and are degenerating; the fourth, however, is normal and lies at the centre of the protoplast. The degenerating nuclei are scattered inside the protoplast; in one instance, four such could be made out in one of the daughter protoplasts and two in the other (Text-Fig. 27). These nuclei are no longer functional and do not play any further part in the life-cycle; the fourth one alone, which is large and normal, is functional. Thus, two ova are organized in each oogonium.

In a few instances, four ova were noticed in the oogonium of the present alga (Text-Figs. 29 and 30). According to Moore (1928, p. 429) the production of four ova is common in *P. fastigiata*. The production of four ova in the present alga indicates that the condition observed normally, two ova in each oogonium, is a reduced condition; and that out of the eight nuclei formed, only two normally function; that some of the degenerating nuclei, however, are potentially capable of functioning is indicated by the rare occurrence of four ova in an oogonium.

It is interesting to note that in some of the other Fucales, *e.g.*, *Xiphophora* (Barton, 1893; Mitchell, 1941), *Ascophyllum* (Oltmanns, 1889), *Bifurcaria* (Rees, 1933; Laing, 1941) and *Hormosira* (Gruber, 1896), four ova are produced normally; and in some others, *e.g.*, *Sargassum* (Abe, 1938; Kunieda, 1928; Kunieda and Suto, 1940; Tahara, 1913, 1924–27; and Tahara and Shimotomai, 1926), *Coccophora* (Tahara,

1929), *Carpophyllum* (Dawson, 1940), and *Himanthalia* (Oltmanns, 1889), the oogonium contains only one ovum. The condition in *Fucus*, where eight ova are produced (Thuret and Bornet, 1878; Oltmanns, 1889), all the eight nuclei after the meiotic division being functional, represents a primitive condition (Fritsch, 1945, p. 370), and the condition seen in *P. canaliculata* is to be considered more advanced than instances like *Fucus* and those producing four ova, and less so than those in which only one ovum is produced. The variations in the mode of degeneration of the supernumerary nuclei are discussed in another section.

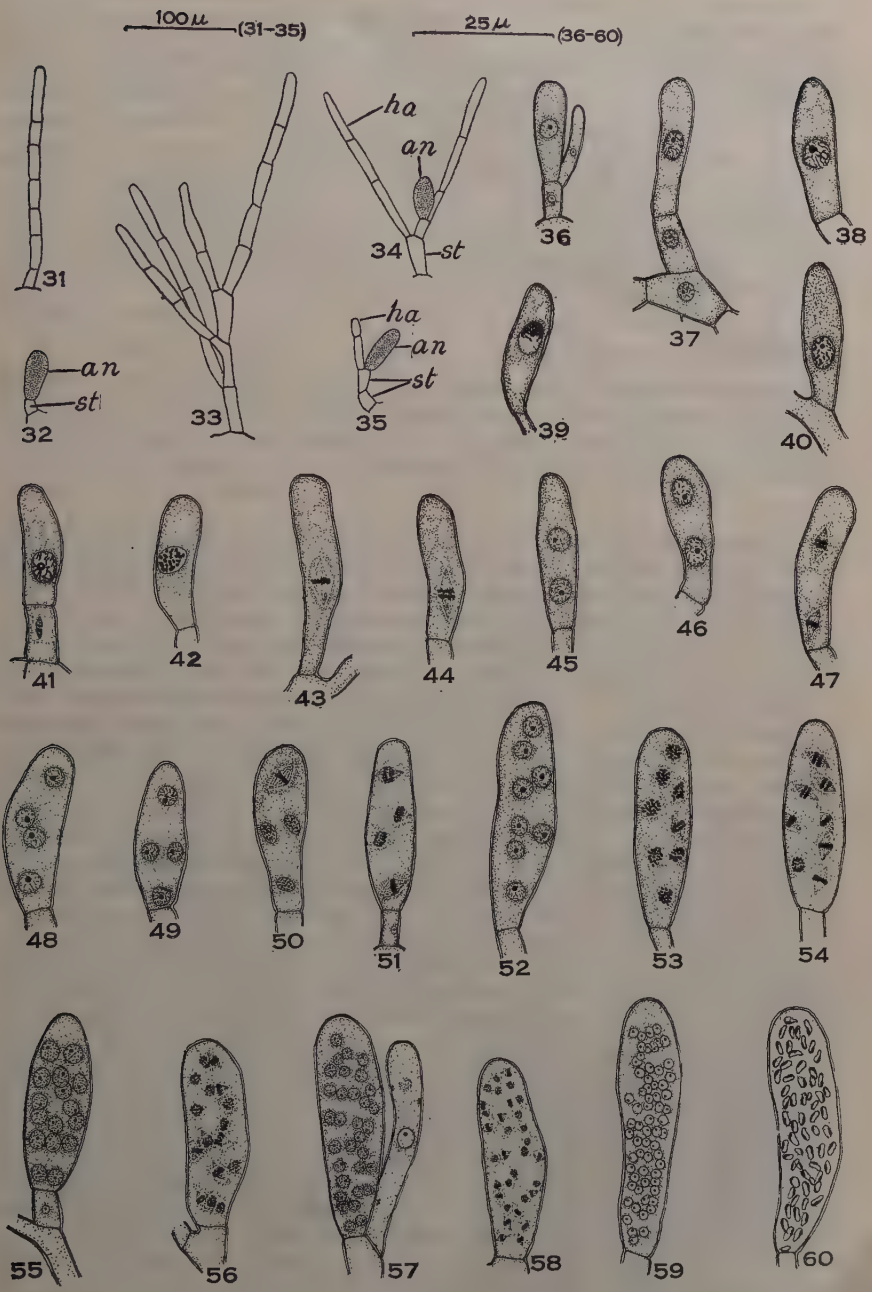
### *The Antheridia*

Like the oogonia, the antheridia also arise from the lining of the conceptacle, and their number exceeds many times that of the oogonia. They do not project to any great extent into the cavity of the conceptacle, but are confined to the floor of the conceptacle chamber.

The antheridium is seen borne on a short stalk cell, or on a branched paraphyses (Text-Figs. 32, 34 and 35). Both types occur mixed in one and all the conceptacles. However, only one antheridium is borne on each paraphysis. The antheridia in the figures cited were taken from mature conceptacles and were in a mature condition; hence, no more changes are likely to take place as far as these types of paraphyses are concerned, *e.g.*, production of a branch or more antheridia. The state represented in Text-Fig. 32, one antheridium on a stalk cell, has been known to occur commonly in *Pelvetia fastigiata* (Moore, 1928).

The antheridial initial arises as a small papilla from a cell of the lining layer. The papilla is soon cut off by a wall. The subsequent development of the papilla leading to the production of an antheridium takes place in different manners. In the simplest case, the papilla grows and divides into two, forming a stalk cell "*st*" and the antheridium proper "*an*" (Text-Fig. 32). In the second instance, the stalk cell might have divided after cutting off an antheridium, the upper cell often producing a hair "*ha*"; or the papilla which grows out may have divided once before cutting off an antheridium, the upper cell producing a hair as well (Text-Fig. 35). The third instance (Text-Fig. 34) could be derived from one like that shown in Text-Fig. 35, if we assume that the lower stalk cell also produces a hair; it may be also that the antheridium is produced on one of the two branches initiated by the stalk cell. In whatever manner they arise, the antheridia are always confined to the basal part and only one antheridium occurs on each of the paraphyses.

The antheridium itself is hardly distinguishable from a cell of the paraphyses in the early stages. But soon it becomes conspicuous as the cell concerned grows much larger than the cells of the paraphyses and the nucleus also enlarges to almost double the size of the ones seen in the latter (Text-Fig. 36). The resting nucleus in the antheridium shows a prominent nucleolus and a lightly stained reticulum. The nucleus of the antheridium undergoes six successive divisions, the first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FIGS. 31–60

TEXT-FIGS. 31–60. *Pelvetia canaliculata.* Paraphyses and development of the antheridium Figs. 31 and 33. Unbranched and branched paraphyses from the lining of the conceptacle. Fig. 32. Antheridium on stalk cell. Fig. 34. Antheridium on paraphyses with prominent branches. Fig. 35. Antheridium on slightly branched paraphyses, two stalk cells and one hair. Fig. 36. Antheridium rudiment with prominent nucleus. Figs. 37 and 38. Nucleus of antheridium in prophase of meiotic division. Fig. 39. Synizesis. Figs. 40 and 41. Pre-diakinetic stages, bivalents shortened and thickened. Fig. 42. Diakinesis. Fig. 43. Metaphase of I Division. Fig. 44. Early anaphase of I Division. Figs. 45 and 46. Two-nucleate stages; note nuclei in prophase. Fig. 47. II Division, one nucleus in metaphase and the second in early anaphase. Figs. 48 and 49. Four-nucleate stages; nuclei in prophase. Figs. 50 and 51. III division; in Fig. 50, three of the nuclei are in prophase and one in metaphase. Fig. 52. Eight-nucleate stage, nuclei in prophase. Figs. 53 and 54. IV Division; note spindle views and polar views of division figures. Fig. 55. Sixteen-nucleate stage, nuclei in prophase. Fig. 56. V Division. Fig. 57. Thirty-tw -nucleate stage, nuclei in prophase. Figs. 58 and 59. VI division and sixty-four-nucleate stage. Fig. 60. Spermatozoids organized.

of which is meiotic. Sixty-four nuclei result ultimately and each one of them becomes the nucleus of a spermatozoid which is organised inside the antheridium. The stages in the divisions of the nuclei inside the antheridium are represented in Text-Figs. 37 to 60 and Pl. I, Figs. 3, 4, and 5.

During the prophase of the meiotic division, a number of chromosome threads become evident in the nucleus (Text-Fig. 37) and these become more and more deeply stained as the stage advances (Text-Fig. 38); and in synizesis, the chromosomes are seen lying in a "knotted mass" appressed to the nuclear membrane on one side (Text-Fig. 39). On very careful examination the nucleolus could be recognized in this "knotted mass". In the next stage, the chromosomes appear as if "recovered" from synizesis and are very much shortened and more or less evenly distributed in the nuclear cavity (Text-Figs. 40 and 41). There are indications at this stage that they are bivalent in nature. In diakinesis (Text-Fig. 42), a large number of bivalents are seen inside the nuclear cavity. The nuclear membrane is still intact while the nucleolus has disappeared. The number of bivalents could not be accurately estimated owing to the small size of the nuclear figure; however, over 20 ($n$) could be counted. At metaphase, the bivalents appear arranged rather compactly in a plate at the equator of the spindle (Text-Fig. 43; Pl. I, Fig. 3). No centrosomes could be recognized at the poles of the spindle. After anaphase (Text-Fig. 44) and telophase, two daughter nuclei are organized inside the antheridium (Text-Fig. 45). The daughter nuclei do not appear to pass into a typical resting condition, but are always seen in a prophasic stage (Text-Figs. 45 and 46). The subsequent divisions, the second (Text-Fig. 47), the third (Text-Figs. 48 to 52; Pl. I, Fig. 4), the fourth (Text-Figs. 53 to 55), the fifth (Text-Figs. 56 to 57; Pl. I, Fig. 5) and the sixth (Text-Figs. 58 and 59), all appear to take place in quick succession and simultaneously in all the nuclei in the antheridium. One single instance of an exception to this was found in the third division (Text-Fig. 50), where one nucleus was in metaphase while the remaining three were still in prophase. The nuclei in the four-, eight-, sixteen- and thirty-two-nucleate stages

were always seen to be in a prophasic condition which again indicates that the divisions follow one another in quick succession.

After the sixth division in the antheridium, 64 nuclei are formed; each forms the nucleus of a spermatozoid which is organized inside the antheridium. Owing to the smallness of the object and the large number of spermatozoids present, it was not possible to study how this organization is brought about. The spermatozoid is pear-shaped, shows a small nucleus, a very lightly stained body (chromatophore?) and a darkly stained eye-spot or stigma.[4] The cilia could not be recognized at this stage or in fixed and stained material (Text-Fig. 60). The appearance of the spermatozoid in the living condition will be considered later.

It may be interesting to mention here that meiotic division of the nucleus and the following nuclear changes in the antheridium appear to have been recorded only in the following few species of Fucales: *Fucus vesiculosus* (Yamanouchi, 1909), *Sargassum hornerii* (Kunieda, 1926, 1928) and *S. confusum* (Abe, 1933). In the last mentioned alga, only the first, second and third divisions have been observed.

Yamanouchi (1909, p. 179) states that in *Fucus vesiculosus*, at the end of the fifth division in the antheridium, when 32 nuclei are formed, cell-plate formation is initiated between the nuclei, and the antheridium, consequently, is divided into thirty-two cells. The sixth division takes place next and this division also is accompanied by thin partition walls between the nuclei so that the antheridium becomes 64-celled and in each one of them a spermatozoid is produced. Similar observations have been made on this alga by Thuret (1854) and Behrens (1886). Kylin (1916, p. 198, Pl. II, Figs. 4 and 5) has recorded a similar state in the antheridium of *Fucus serratus*. Richard (1932, p. 436) has also recorded formation of partition walls in the antheridium of a species of *Fucus*. Moore (1928, pp. 430–31, Fig. 24) states that in the antheridium of *Pelvetia fastigiata* evanescent walls appear at the 32-nucleate stage, but has observed no partition in the 64-nucleate stage.

In the present alga, the writer was not able to discern any partition wall between the nuclei in the 32-nucleate stage or in the next stage. The nuclei appear to lie free in the antheridium; however, it must be stated that from this stage onwards, the cytoplasm tends to accumulate around the nuclei. This may be seen to some extent in Text-Figs. 58 and 59. It has been recognized (Fritsch, 1945, p. 370) that the production of four or eight ova is largely confined to the less specialized members of Fucales and an oogonium producing eight eggs represents the primitive condition. In producing a lesser number of eggs (two) *Pelvetia canaliculata* represents a further advanced stage. The suppression of partition walls in the antheridium appears to be another point of advance over the other members of the Fucaceæ, *e.g.*, *Fucus* and *Pelvetia fastigiata*.

[4] The spermatozoid is described in detail in Part III of this series

## Discussion

### *Development of the Conceptacle*

It may be interesting to point out here the difference which *Pelvetia canaliculata* exhibits in the development of the conceptacle when compared with the other members of the Fucales. Nienburg (1913, p. 25) has given a diagrammatic representation to illustrate the scheme of division in the forms he investigated. The first division of the initial is transverse in *Himanthalia* and *Fucus* oblique in *Ascophyllum*, longitudinal (rarely oblique) in *Pelvetia fastigiata* and by a curved wall in *Cystoseira*, *Halidrys*, *Sargassum* and *Pycnophycus*. The upper cell, termed "tongue-cell", cut off by the transverse division, elongates a little (*Sargassum*), or in some species grows into a hair (*Cystoseira*), or shows no development (*Fucus*).[5] It does not play any important part in the further development of the conceptacle. The basal cell, by further divisions, gives rise to the entire lining of the conceptacle (*Sargassum*, *Cystoseira*, *Halidrys*); or solely to the tissues occupying the floor of the conceptacle (*Fucus*). The greater part of the lining in the latter instance and the uppermost part in the former are contributed by the adjacent cells.

In *Pelvetia fastigiata* (Nienburg. 1913) the two cells produced as a result of the first longitudinal division of the initial, next divide transversely cutting off two basal cells. The upper cells grow into short hairs while the two basal cells divide irregularly and form the floor of the conceptacle. The greater portion of the sides arise from adjacent cells. The account of Barton (1891) for *Turbinaria* closely resembles that given for *Pelvetia fastigiata*; but, Blomquist's (1945) account for *Turbinaria turbinata* shows that the development in that plant is exactly similar to that described by Simons (1906), Nienburg (1913) and Rao (1946) for *Sargassum*.

*Pelvetia canaliculata* resembles *P. fastigiata* in the first division of the initial which is longitudinal. The further development of the two cells formed by the initial up to the differentiation of the lining of the conceptacle is at variance from that of all the other Fucales hitherto described. As already mentioned, the two daughter cells of the initial undergo repeated divisions, and only at a later stage, when the cavity of the conceptacle has become well defined, do the cells cut off cells towards the base as well. The basal cells thus cut off, by further divisions (periclinal and anticlinal), form ultimately the entire lining of the conceptacle.

Nienburg (1913, p. 22) has indicated from a comparison of the different stages in the development of the conceptacles close to the apical region (in *Cystoseira* particularly) that the development takes place rather quickly. The rapid successive anticlinal divisions of the initial and their daughter cells, together with the 'postponement' of transverse division to a later stage, obviously facilitates, perhaps, a

[5] Sometimes it forms a hair in *Fucus spiralis* (Bower, 1880).

rapid development of the conceptacle in *Pelvetia canaliculata* described here. This claim is supported by the fact that suitable material for the study of the development of the conceptacle is hard to come by, an experience shared by earlier workers (Oltmanns and Nienburg).

In *Pelvetia canaliculata* no hairs are developed in the rudimentary stage in connexion with the development of the conceptacle. In *Himanthalia* (Bower, 1880; Oltmanns, 1889; Nienburg, 1913; Naylor, 1949) the conceptacle initial shows a trichothallic origin, which reminds one of the origin of the apical cell in *Fucus* (Nienburg, 1931). The remarks of Fritsch (1943, p. 81; 1945, p. 365) in this connexion are worth quoting here. Fritsch (1945, p. 365) states that "The development of the conceptacle of *Himanthalia* shows that the tongue-cells of Cystoseiraceæ and Sargassaceæ, which are no doubt homologous with the upper cell of the rudiment in the Fucaceæ, represent vestigial hairs which are suppressed to a varying degree. This means that the conceptacles take their origin to a more or less appreciable extent from the basal cell of a hair, and it is profitable in this connexion to recall the perfectly similar derivation of the apical cell in the young embryo of *Fucus*.[6] The initial cells of the conceptacles may, in fact, be regarded as the equivalents of branch initials, which, like the latter, become lodged in a depression (the conceptacle), although diverted to a special purpose."[7] Adventitious branches have been observed to develop from the basal cells of hairs in the cryptoblasts in *Notheia* (Gruber, 1896) and *Fucus ceranoides* (Skrine *et al.*, 1932); the latter authors also discuss the morphological significance of regeneration of shoots from hair-pits.)

In *Pelvetia canaliculata* no hairs are produced in connexion with the development of the conceptacle. The initial, as already mentioned, divides longitudinally into two, the divisions are repeated several times by the successive daughter cells and transverse divisions to form the lining of the conceptacle begin at a later stage only. In the other species, *P. fastigiata*, hairs have been recorded in connexion with the development of the conceptacle by Nienburg (1913) and Moore (1928), and the latter has also recorded cryptoblasts on the thallus. It is possible to make out a reduction series from *Himanthalia* where the trichothallic origin is conspicuous to *Fucus* where it is seen as a vestige, and then *Pelvetia canaliculata* where the hairs are completely absent. The condition in this alga appears to represent a reduced state, where several unnecessary stages appear to be completely suppressed.

The writer would like to point out here what appears to be misleading citations by some earlier authors. Moore (1928, p. 420) states in connexion with the development of the conceptacle in *Pelvetia fastigiata* as follows: "The most important contribution was made by Bower, however, working on various species of the Fucaceæ, including *Pelvetia canaliculata*, work which has been generally accept d."

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[6] Reference to a page number omitted by the writer here while quoting.

[7] Reference to Skrine, Newton and Chater (1932).

The reference to Bower is to his paper on the development of the conceptacle in the Fucaceæ cited here, Bower (1880). The writer, on careful scrutiny, finds that nowhere in Bower's paper is even the name *Pelvetia* or *P. canaliculata* ever mentioned. Bower has dealt with some of the other Fucaceæ Moore's reference to Holtz (1903) connecting *P. canaliculata* (Moore, 1928, p. 421) appears to be an error, for, elsewhere in the same account the plant concerned, *P. fastigiata*, is cited correctly.

Delf (1939, p. 231) in a discussion relating to the conceptacle states as follows: "In *Halidrys siliquosa* and *Cystoseira* there is little segmentation, the primary hair degenerating after one or two divisions (Nienburg, 1913), while in *Fucus*, *Bifurcaria* and *Sargassum* no further divisions take place, but the upper cell becomes elongated, pointing upwards like a short tongue towards the narrow ostiole and degenerating very early, while the lower cell divides to form the layer of cells lining the floor of the conceptacle." In a footnote to this sentence quoted, she observes: "In *Pelvetia canaliculata* and in *Ascophyllum*, the lower half of the initial cell divides, forming irregular projections into the cavity formed by the active development of adjoining tissues. The further fate of these projections is in doubt." Delf does not cite any reference to these two algæ mentioned immediately above, but it appears from the context as well as the names of the several other genera mentioned that she is referring to Nienburg (1913) unless the reference be to unpublished work of the author. However, it is to be noted that Nienburg has studied the development of the conceptacle in *P. fastigiata* and not *P. canaliculata*, and he has stated in particular that he could not obtain favourable material of this latter alga from either Norway or Plymouth; he, therefore, obtained *P. fastigiata* from California. The observations of the writer on *P. canaliculata* appear to be the only account for this alga in regard to the development of the conceptacles and his observations are totally at variance with the statement of Delf cited above for the same alga.

Again, Delf (*op. cit.*) states: "According to Moore (1928) the conceptacle of *Pelvetia fastigiata* is initiated by a group of hairs which behave in a similar manner," etc. Moore (1928, p. 426) does not state that the conceptacle is initiated by a group of hairs, but states: "The initial cell appears depressed..... Next, the initial cell divides longitudinally; both daughter cells cut off basal cells; the basal cells continue to divide and form the wall of the bottom of the conceptacle; meanwhile division and growth take place in the neighboring cells." After describing the formation of the lining of the conceptacle the author adds (*op. cit.*, 428): "The division of the basal segments of the initials form a mound in the bottom, and there are various protruding initials in the early stages..... The upper segments of the initials also divide and grow into two filaments several cells in length which function apparently as hairs in the conceptacle." The use of the word *initials* to mean more than one structure is apt to be confusing. The *protruding initials* of Moore are probably the beginnings of paraphyses in the conceptacle as it appears from the illustration given

(Fig. 9, p. 427) and the *filaments* produced by the upper segments of the *initials* are homologous to the tongue-cells or hairs produced (*cf.* Nienburg, 1913, pp. 18–19. Fig. 6). Moore appears to be not quite sure whether the conceptacle originates from a single cell or two; for, it is stated elsewhere (*op. cit.*, p. 433) that the conceptacle develops from *two epidermal initials*. It seems possible that Delf's reference to "a group of hairs" while citing Moore's account, is due to a confusion with Moore's expression "protruding initials". Nienburg's account for the same alga is clear and convincing.

*The Supernumerary Nuclei in the Oogonium*

The writer would like to add here a few remarks concerning the supernumerary nuclei in the oogonium and the process of their degeneration as observed by him in *Pelvetia canaliculata*. Such nuclei have been observed in all instances where the number of ova present is less than eight, *i.e.*, four, two and one; and they have been described as being extruded as such, degenerating, or cut off with a little amount of cytoplasm (Oltmanns, 1889; Farmer and Williams, 1898; Gardner, 1910; Abe, 1938; Kunieda, 1928; Tahara, 1913, 1924–27, 1929; Tahara and Shimotomai, 1926; *cf.* also Fritsch, 1945, pp. 370 and 372).

In the oogonium of *Pelvetia canaliculata*, according to Oltmanns (1889, pp. 87–88), the supernumerary nuclei are extruded at the equator of the oogonium and become visible when the oogonium swells and the ova begin to round off, or they are seen sometimes at an earlier stage. They are six in number and are seen lying in a groove formed between the two ova when they swell. Oltmanns cites the figures given by Thuret, which is frequently reproduced in text-books. Thuret and Bornet (1878, p. 46, Pl. XXII, Fig. 13) found these bodies reacting to tests for cellulose like the outer wall of the oogoniun ana presumed that they are detached portions of the wall resulting when the oogonium parts into two. Oltmanns (1889, p. 87) states that they are not cell-wall constituents as supposed by Thuret, but are the supernumerary nuclei.

The observations of the writer on the same alga leads to the inference that the process of degeneration of the supernumerary nuclei is not uniform always. It was expected that these 'bodies' would be found readily in the equatorial region of the oogonium; but no clear demonstration of them could be obtained. In fact, during the course of observations on the living and fixed material, the writer was struck by the almost total absence of such "bodies" anywhere in the oogonium. When the contents of the conceptacles were in the process of extrusion, they were removed with the aid of sterilized glass needles and placed in candle filtered sea-water and kept under observation for long periods. An enormous quantity of material has been so examined on different occasions during the summer of 1946. In three or four oogonia only one or two small "bodies" were seen situated at the opposite poles in the equatorial region of the oogonium. It was more common to find inside the oogonial chamber one or two spherical bodies, many times smaller than the ova. These small spherical bodies are probably

the ones observed at the opposite poles of the equatorial region of the oogonium, mentioned earlier, which have rounded themselves off. Spermatozoids were also observed to swim around these bodies. They were kept under observation in cultures but they did not show further development. Sections of material fixed during these observations and of receptacles fixed earlier, shed some light on this point. In a few instances, a small, more or less three-sided (in section) body was seen, sometimes two, at the equatorial region (Pl. I, Fig. 9 *a*) fitting like a plug in the niche formed by the two halves of the oogonial wall. In other instances (Text-Fig. 28 *a*), in longitudinal sections of the oogonium, a small, somewhat three-sided (in section) bit of protoplast possessing a nucleus was observed, cut off near the equatorial region of the oogonium. The nucleus in this protoplast showed no nucleolus and appeared to be in a state of degeneration. A nucleus of similar type was seen at the opposite side in the other ovum (Text-Fig. 28 *a*); very probably, this nucleus would also later be cut off together with some cytoplasm, and one such instance has also been observed. Evidently, from the fate of such bodies, observed in the living specimens, it can be stated that such protoplasts represent aborted ova. The stage just described is a much earlier one than that shown in Pl. I, Fig. 9. It is possible that in the latter too, the smaller bodies seen represent aborted ova, which have already shrunken very much. It may be that there are gradations in the degree of shrinkage experienced by such ova. Some may persist in a condition of the nucleus being surrounded by cytoplasm and get extruded with the other normal oogonial contents. Abortion is not only graded but it may not occur to some nuclei, as clearly has happened in oogonia where four ova are produced (Text-Figs. 29 and 30). Among the liberated oogonia, very few containing four ova have been seen (these were intermediate in size, much larger in size than the "bodies" referred to earlier, but smaller than the normal ova) and these ova, presumably after fertilization, divided once or twice but not further; they degenerated while the two ova from normal oogonia developed. It is interesting to mention in this connexion that in *Sargassum*, where usually only one ovum is produced in the oogonium, Tahara (1927, p. 145) has induced experimentally the otherwise degenerating nuclei to function; the germlings resulting from these were, however, noticed to be abnormal.

Again, in instances where aborted ova are produced as well as four ova in the oogonium, four more nuclei have to be accounted for. In all normal cases it was observed that degeneration of the three supernumerary nuclei in each ovum begins early and may be evident in the eight-nucleate stage itself. It is possible that degeneration of some nuclei is so complete that they are re-absorbed into the cytoplasm of the ovum.

## Summary

A detailed account of the origin and development of the conceptacle in *Pelvetia canaliculata* is given for the first time. The conceptacle

initial divides longitudinally first unlike in the other members of the Fucales where the first division is transverse.

The development of the ooginia and antheridia is dealt with in considerable detail.

Meiotic division of the nucleus during gametogenesis in the oogonium and the antheridium is described as well as the following divisions, and all the stages are illustrated. The number of chromosomes appear to be about 22 (*n*).

Two ova are produced in each oogonium and sixty-four spermatozoids in each antheridium.

The variations observed in the degeneration of the supernumerary nuclei in the oogonium are described and discussed.

The development of the conceptacles in *Pelvetia canaliculata* is discussed in relation to the earlier observations on the other members of the Fucales.

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## EXPLANATION OF PLATE I

FIG. 1. L.s. of apex with conceptacle initial and apical furrow to the left, ×450.

FIG. 2. T.s. of receptacle showing conceptacle with paraphyses and oogonial rudiment, *O.*, ×95.

FIG. 3. Nuclear division in the antheridium; I division metaphase, ×830.

FIG. 4. Nuclear division in the antheridium; III division metaphase, ×830.

FIG. 5. Nuclear division in the antheridium; V division metaphase, ×830.

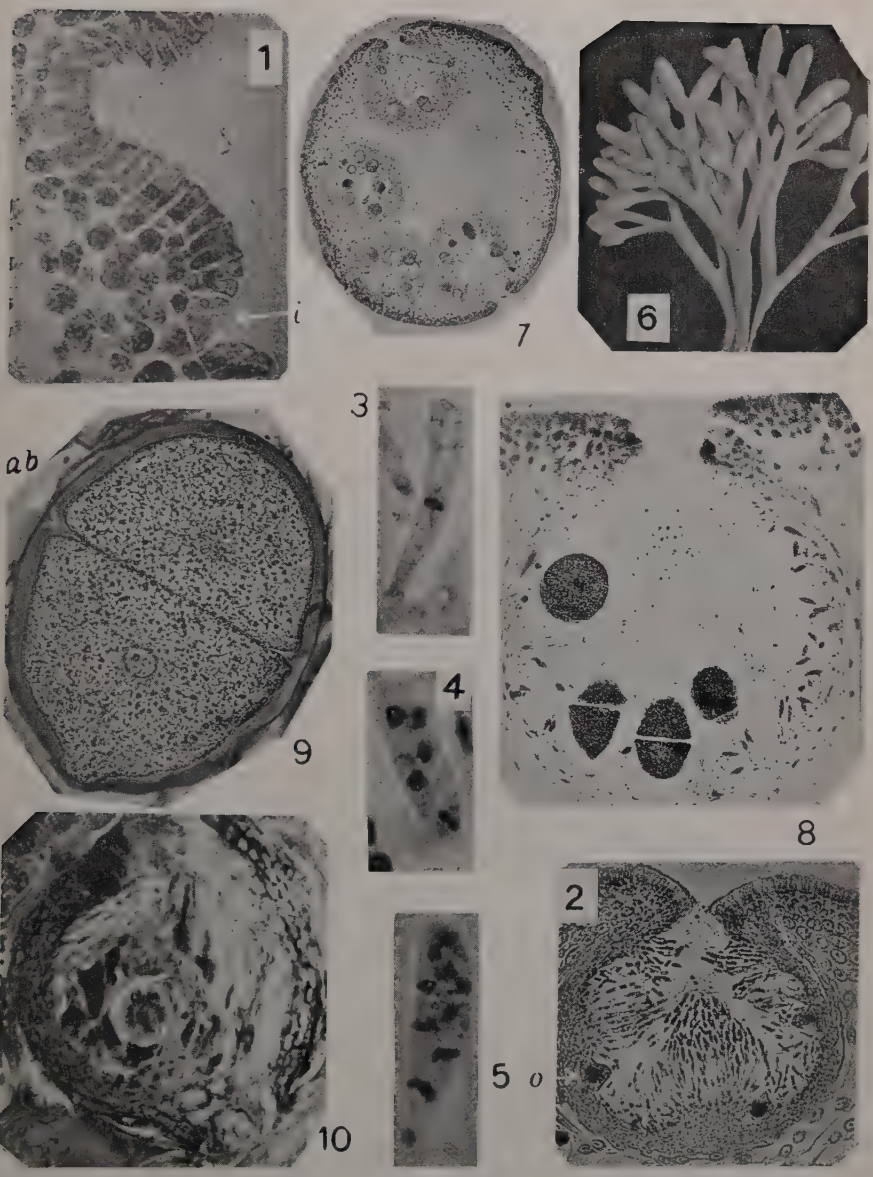
FIG. 6. Fruiting plant of *Pelvetia canaliculata* (a portion of the thallus). Note receptacular ends of the fronds. (Photograph by courtesy of Dr. M. Knight.), ×¾.

FIG. 7. T.s. of receptacle showing number of conceptacles with reproductive bodies. Note absence of tissue at the centre, ×60.

FIG. 8. T.s. of receptacle showing conceptacle with oogonia and antheridia (on the right), ×75.

FIG. 9. Oogonium with two ova, almost mature, ×440.

FIG. 10. T.s. of receptacle showing ascocarp of *Mycosphærella* (?). Note asci and ascospores, ×525.




R. Subrahmanyan

# CYTOTAXONOMICAL STUDIES IN THE GENUS *LANTANA*

By A. T. Natarajan and M. R. Ahuja

*Botany Division, Indian Agricultural Research Institute, New Delhi*

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*Lantana* L. a genus of Verbenaceæ is a very common shrub, native of America, now growing wild in many parts of India. It is grown as a hedge plant but is more commonly found as a weed in waste lands as well as cultivated and pasture lands. Once established, it is very difficult to eradicate it.

There are about 75 species in the genus *Lantana* (Bailey, 1949). As they are very confusing it is very difficult to assign the various forms to different botanical species of *Lantana*. The cytological information available with regard to this genus is very meagre. The chromosome number of *L. camara* L. is stated to run in a polyploid series with a basic number of $n = 11$ (Singh, 1951; Tandon and Chandi, 1955; Tandon and Bali, 1955; Sen and Sahni, 1955) and the chromosome number of *L. trifolia* is $2n = 48$ (Paterman, 1935). The present study was undertaken to study the cytology of different forms of *Lantana*, both wild and cultivated, to see how far the cytological data coupled with morphological characters can help in understanding the taxonomy of this genus.

## Material and Methods

Twenty-two different types of *Lantana* were collected for this study which included material from different parts of India, *i.e.*, Bombay, Nilgiris, Calcutta and Delhi. Most of the specimens were naturally occurring as wild forms. However, a few horticultural types were also studied from those maintained in various gardens in Delhi. All these plants were identified at the Herbarium, Botanical Garden, Sibpur, Calcutta. The following species and varieties were studied:—

1. *L. camara* L.
   - (*a*) var. *mutablis* Bailey 10 types
   - (*b*) ,, *mista* ,, 4 ,,
   - (*c*) ,, *crocea* ,, 3 ,,
   - (*d*) ,, *nivea* ,, 1 type
   - (*e*) ,, *sanguinea* ,, 1 ,,
2. *L. lilacina* Desf.
3. *L. involucrata* L.
4. *L. indica* Roxb.

*Cytological Methods*

Meiosis in the pollen mother cells was studied from young buds fixed in Carnoy's fluid (6 : 3 : 1) for 24 hours. The anthers were smeared in aceto- or propino-carmine. The slides were analysed when temporary and made permanent by passing through butyl alcohol series. The chromosome numbers were confirmed from leaf tip smears also, for which, young leaf-tips were pre-treated with saturated solution of paradichlorobenzene for 3 hours and fixed in acetic alcohol (1 : 3) for 24 hours. Feulgen squashes were made and the chromosome numbers were determined.

## Observations

Study of the most important morphological characters were made to distinguish the various species and varieties under study. These characters are tabulated in Table I.

*Cytological Observations*

*L. camara* L.—This is the commonest species of *Lantana*, which grows luxuriantly and many types are met with. Most of the types have recurved prickles on the stem while some of the cultivated types have smaller prickles or they are even without prickles. Five different varieties of this species have been studied.

*L. camara* L. var. *mutablis* Bailey.—Ten different types were studied and they were found to show different chromosome numbers in a polyploid series, *i.e.*, $2n = 22$, 33, 44 and 66. One type was showing $2n = 22$, with eleven bivalents formed at metaphase I (Plate II, Fig. 1) followed by normal separation leading to proper tetrad formation. Three types were showing a chromosome number of $2n = 33$, with varying metaphase configurations forming trivalents, bivalents and univalents (Plate III, Fig. 9). The analysis of metaphase I is given below for 8 cells.

| III | II | I |
|---|---|---|
| 8 | 3 | 3 |
| 3 | 9 | 6 |
| 6 | 4 | 7 |
| 7 | 6 | .. |
| 9 | 3 | .. |
| 5 | 8 | 2 |
| 8 | 4 | 1 |
| 6 | 6 | 3 |

In anaphase there was occurrence of laggards varying from 1 to 4. More than 4 spores were found to be formed in all the three types.

Five types showing $2n = 44$ were studied (Plate II, Fig. 3). They were showing varying configurations at metaphase I. Few types were found to form 22 bivalents, while there were formation of quadri-, tri-, bi- and univalents in others. The analysis of 8 cells at metaphase I is given below:—

| IV | III | II | I |
|---|---|---|---|
| 2 | 4 | 10 | 4 |
| 2 | 6 | 7 | 4 |
| 2 | .. | 16 | 4 |
| 2 | .. | 14 | 8 |
| 2 | 4 | 8 | 8 |
| 3 | 4 | 7 | 6 |
| 2 | .. | 12 | 12 |
| .. | .. | 22 | .. |

Excepting the types F and H (*vide* Table I) other 3 types showed laggards varying from 1 to 4 at anaphase I. There was also polyspory in these types.

One type showing $2n = 66$ was examined. This is a new number for this genus. This plant was found to occur along with the 44 chromosome plants and was almost indistinguishable from them. At metaphase I varying configurations involving univalents to heptavalents were seen (Plate II, Fig. 2; Plate III, Fig. 6). At anaphase there were as many as 7 laggards. Polyspory was common. The analysis of 8 plates of metaphase I is given below:—

| VII | VI | V | IV | III | II | I |
|---|---|---|---|---|---|---|
| .. | 1 | .. | 2 | 3 | 18 | 7 |
| .. | .. | .. | .. | 3 | 22 | 13 |
| .. | .. | .. | .. | 4 | 19 | 16 |
| .. | .. | 2 | 2 | 3 | 16 | 7 |
| .. | .. | .. | 2 | 4 | 17 | 12 |
| .. | .. | 1 | 3 | 8 | 10 | 5 |
| 1 | 1 | 1 | 2 | 3 | 13 | 5 |
| .. | 1 | 3 | 4 | 1 | 10 | 6 |

*L. camara* L. var. *mista* Bailey.—Four types of this variety which were studied were all found to have $2n = 44$. All these types were characterised by spiny stem. At metaphase I one type was showing normal 22 bivalents followed by normal tetrad formation. Other types were showing various metaphase configurations with quadri-, tri-, bi- and univalents similar to the previous 44 chromosome type plants tabulated already. There were laggards at anaphase and more than four spores are formed.

TABLE I

| No. | Species and variety | Type | Habit | Nature of prickles | Leaf character | Flower colour | Bracts and Bracteoles | Seed setting | Chromosome number |
|---|---|---|---|---|---|---|---|---|---|
| 1 | *L. camara* L. var. *mutablis* Bailey | A | Huge woody shrub, 8′ tall | Pubescent | Rough, 2–4″ long, 1–2″ broad | Yellow to pink | Not prominent | Nil | 33 |
| 2 | do. | B | Spreading shrub, 3′ high | Slightly spiny | 1–2½″ long, ½–1″ broad | Light pink | do. | Nil | 44 |
| 3 | do. | C | Moderate shrub, 4–5′ high | Pubescent | 1–2″ long, 1–2″ broad | Yellowish pink | do. | Good | 44 |
| 4 | do. | D | Climbing shrub, 6–8′ high | Very fine spines | 2–1½″ long, 1–1½″ broad | Pink | do. | Occasional | 66 |
| 5 | do. | E | Trailing shrub, 2–3′ high | Slightly spiny | 2–3″ long, 1½–2″ broad | Scarlet red | do. | Nil | 33 |
| 6 | do. | F | Spiny shrub, 4–5′ high | Prominent recurved prickles | 2½″ long, 2″ broad | Rosy | do. | Good | 44 |
| 7 | do. | G | Moderate shrub, 4–5′ high | Slightly spiny | 2″ long, 1″ broad | Yellowish orange | do. | Good | 22 |
| 8 | do. | H | Scabrous shrub, 5–6′ high | do. | 4″ long, 2″ broad | Pink | do. | Nil | 33 |
| 9 | do. | I | Moderate shrub, 4–5′ high | Prominent recurved prickles | 2–3″ long, 1–2″ broad | Scarlet | do. | Poor | 44 |
| 10 | do. | J | Spiny shrub, 5–6′ high | Recurved prickles | 2–2½″ long, 1½″ broad | Rosy | do. | Good | 44 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 11 | var. *mista* Bailey | K | Woody, shrub, 8–9′ high | do. | Linear rough, 2–3″ long, 1″ broad | Pink | do. | Occasional | 44 |
| 12 | do. | L | Moderate shrub, 4–5′ high | Slightly spiny | Smooth, 2″ long, 1″ broad | Yellowish to pink | do. | Nil | 44 |
| 13 | do. | M | Spiny shrub, 6–8′ high | Prominent spines | do. | Orange red | do. | Nil | 44 |
| 14 | do. | N | Sturdy shrub 4–5′ high | Recurved thick prickles | 2½″ long, 2″ broad | Deep red | do. | Good | 44 |
| 15 | var. *crocea* Bailey | O | Small shrub 1½′ high | Pubescent | Rough 2½″ long, 1½″ broad | Deep yellow | Prominent | Nil | 22 |
| 16 | do. | P | Erect shrub, 4′ high | do. | 1–1½″ long, ½″ broad | do. | do. | Nil | 22 |
| 17 | do. | Q | do. | do. | 2–3″ long, 1″ broad | do. | do. | Nil | 22 |
| 18 | var. *nivea* Bailey | R | Erect shrub, 5–6′ high | do. | Soft, 3–5″ long, 1–2″ broad | Creamish white | do. | Good | 22 |
| 19 | var. *sanguinea* Bailey | S | Erect shrub, 3–4′ high | Prominent spines | 1–2½″ long, 1–2″ broad | Yellow to red | Not prominent | Good | 44 |
| 20 | *L. involucrata* L. | T | Trailing under shrub | Non-spinous | 1½″ long, ¾″ broad | Lilac | Prominent | Nil | 36 |
| 21 | *L. indica* Roxb. | U | Erect shrub, 3′ high | do. | Smooth, 3″ long, 1½″ broad | Pink with white throat | do. | Good | 72 |
| 22 | *L. lilacina* Desf. | V | Uuder shrub, 2′ high | Pubescent | Rough, 2–3″ long, 1–2″ broad | Scarlet | Not prominent | Occasional | 36 |

*L. camara* L. var. *crocea* Bailey.—All the 3 types studied in this variety were found to show $2n = 22$. The stem was non-spiny. The flowers were deep yellow in colour with very prominent bracts and bracteoles. Though at metaphase I, 11 bivalents were formed, anaphase revealed the presence of laggards varying in number up to 4. There were more than 4 spores formed.

*L. camara* L. var. *nivea* Bailey.—The only type examined of this variety showed a chromosome number of $2n = 22$ forming 11 bivalents at metaphase I. There were no meiotic abnormalities.

*L. camara* L. var. *sanguinea* Bailey.—The only type examined of this variety was found to have $2n = 44$. Conspicuous spines were characteristic of this variety. Metaphase configurations showed the presence of quadri-, tri-, bi- and univalents. There were up to 4 laggards and more than 4 spores were formed.

*L. involucrata* L.—This species was found to have $2n = 36$ which is a new number for this genus (Plate II, Fig. 5 and Plate III, Fig. 8). Meiosis was abnormal as seen from the metaphase I analysis given below:—

| III | II | I |
|---|---|---|
| 9 | 4 | 1 |
| 1 | 16 | 1 |
| 3 | 13 | 1 |
| 6 | 8 | 2 |
| 6 | 9 | .. |
| 8 | 6 | .. |
| 7 | 5 | 5 |
| 5 | 8 | 5 |

Anaphase was characterised by the presence of many laggards up to 10. Polyspory up to the formation of 7 spores was also met with.

*L. lilacina* Desf.—Only one type was examined and was found to have $2n = 36$ (Plate II, Fig. 4). This is also a new number for this genus. There was formation of 12 trivalents in few cells while others showed varying configurations as shown by the analysis of metaphase I plates given below:—

| III | II | I |
|---|---|---|
| 12 | .. | .. |
| 7 | 7 | 1 |
| 8 | 5 | 2 |
| 9 | 4 | 1 |
| 9 | 2 | 5 |
| 8 | 6 | .. |
| 9 | 3 | 3 |
| 10 | 3 | .. |
| 11 | 1 | 1 |

Anaphase showed the presence of laggards and polyspory was common.

*L. indica* Roxb.—The chromosome number of this species was found to be $2n = 72$, which is a new number for this genus (Plate III, Fig. 7). At metaphase I they were found to form 36 bivalents followed by normal anaphase separation. There was profuse fruit formation and this species is characterised by the elongation of the inflorescence up to 3 inches after fertilization.

## Discussion

Singh (1951) reported the chromosome number of *L. camara* to be $2n = 44$. Sen and Sahni (1955) found triploid, tetraploid and pentaploid forms of *L. camara*, showing $2n = 33, 44, 55$ respectively. Tandon and Bali (1955) reported the presence of diploid and triploid *L. camara* with $2n = 22$ and 33. Paterman (1935) reported the chromosome number of *L. trifolia* as $2n = 48$. Tandon and Chandi (1955) concluded that the basic number of *L. camara* is 11 and the presence of a species in this genus with $2n = 48$ indicates that this genus has either more than one basic number or has aneuploids.

In the present study, chromosome numbers of 19 types of *L. camara* have been reported indicating the presence of $2n = 22$, 33, 44 and 66 chromosome types in this species. With the finding of a hexaploid ($2n = 66$) there is a record of a complete series from diploid to hexaploid in this species and this series seems to exist only in one variety, *i.e.*, *L. camara* var. *mutablis*.

Meiosis of these types shows that in diploids ($2n = 22$), the chromosomes pair normally forming 11 bivalents (Plate II, Fig. 1). Triploids ($2n = 33$) show an occurrence of 5 to 8 trivalents, 3 to 9 bivalents and 1 to 7 bivalents in different combinations. Some of the tetraploids show normal 22 bivalents formed, while others show 2 to 3 quadrivalents, 2 to 6 trivalents, 7 to 16 bivalents and 4 to 12 univalents in various combinations. 7 to 16 univalents, 10 to 12 bivalents, 1 to 8 trivalents, 2 to 4 quadrivalents, 1 to 3 pentavalents and occasionally 1 heptavalent are seen in hexaploids.

Multiples of 11 in this series suggest that this is the basic number of this group, *i.e.*, *L. camara*. Pairing behaviour of chromosomes in diploids, triploids, tetraploids and hexaploids suggests that there is no homology within the haploid set of 11. The association of 7 chromosomes found in plants with $2n = 66$ is the only exception and this may be probably due to a segmental interchange. From our study, there is thus no evidence to suggest a lower number than 11. Tandon and Bali (1955) found that the majority of pollen mother cells of triploids ($2n = 33$) showed various combinations of tri-, bi- and univalents, the most common combination being an association of 3 trivalents, 6 bivalents and 12 univalents. Sen and Sahni (1955) recorded 8 trivalents, 3 bivalents and 3 univalents in the triploid *L. camara*. However, Tandon and Bali (1955) have recorded that some pollen mother cells in triploid *Lantana* at Delhi showed 16 bivalents and 1 univalent. From the drawing of such a cell, it seems probable that the 17 units seen may consist of some trivalents, bivalents and univalents instead

of 16 bivalents and 1 univalent, as the observation seems to have been made in the polar view. It may hence be concluded that the available data suggest that the basic number 11 may be a primary one to this group.

In the other group of *Lantana* studied so far, the chromosome numbers are multiples of 12, *i.e.*, 36 (*L. involucrata*, *L. lilacina*), 48 (*L. trifolia*) and 72 (*L. indica*). *L. involucrata* forms 1 to 9 trivalents, 4 to 16 bivalents and 1 to 5 univalents at meiosis in various combinations. *L. lilacina* forms 7 to 12 trivalents, 1 to 7 bivalents and 1 to 5 univalents whereas, *L. indica* forms 36 bivalents regularly. The maximum association of 16 bivalents in *L. involucrata* suggests homology within the haploid set of 12, hence may be a secondary polyploid and the primary basic number may be below 12. While further study of all chromosome numbers of different species of *Lantana* will throw light on this point, it can be seen that there are 2 divergent groups of *Lantana* with 2 basic numbers, *i.e.*, 11 and 12. Existence of more than one basic number is common in Verbenaceæ (*Verbena*—5, 7. *Vitex*—6, 8). But 6 and multiples of 6 are common chromosome numbers of this family (Darlington and Janaki Ammal, 1945). *Lippia* and *Stachytarpheta* which are closely related to *Lantana* show numbers which are multiples of 6. From the data available at present, we cannot say whether the basic number 11 was derived from the basic number 12. The relation between 11 and 12 chromosome groups is not clear and may be understood only by producing hybrids between these groups and studying the chromosome association in the hybrids.

Though the previous workers did not go into the details of identifying the varieties (Tandon and Chandi, 1955; Tandon and Bali, 1955; Sen and Sahni, 1955), it appears from the description of plants and chromosome numbers that all of them belong to *L. camara* var. *mutablis*, which is the commonest and well established variety of *L. camara*. The various polyploid forms are so intermixed that it is very difficult to identify them morphologically whether one is $2n$, $3n$, $4n$ or $6n$ plant. It is interesting that other varieties do not show the presence of the polyploid series within the variety as evinced from the study of these types. Each of these types appears to have a constant number of chromosomes with certain well defined morphological characters. For *e.g.*, var. *mista* ($2n = 44$) unlike var. *mutablis* where the spiny character of the stem is very varying from pubescent to thick spiny, has the presence of prominent recurved prickles in the stem as a constant feature.

*Nature of polyploidy*.—Stebbins (1950) has described in great detail the occurrence and characteristics of polyploids and has pointed out the difficulties in classifying them into either auto- or allopolyploids. Much importance can be attached to the various configurations at metaphase I of plant forms which are propagated for a long time vegetatively for horticultural purposes, in reaching conclusions with regard to the nature of ploidy. Of the 4 criteria (Stebbins, 1950), usually used to distinguish between auto- and allopolyploids (*i.e.*,

morphological resemblances, chromosome behaviour, presence or absence of tetrasomic segregation and the fertility of the diploid from which the polyploid is derived), chromosome association at first metaphase of meiosis are the usual source of information concerning the type of polyploidy in a given plant. Swaminathan (1954), while discussing the nature of polyploidy in some species of *Solanum*, section *Tuberarium* has pointed out the various practical difficulties in ascertaining the nature of polyploidy in a long established polyploid plant from present-day studies. The high frequency of trivalents in the forms of *L. camara* with $2n = 33$, and in *L. involucrata*, *L. lilacina* may suggest that they are autotriploid forms by nature. *L. camara* shows an average of 6·5 trivalents, *L. involucrata* 5·6 and *L. lilacina* 9·3. *L. lilacina* appears to be an autotriploid as it shows a maximum association of 12 trivalents. Of the tetraploid forms, some show 22 bivalents at metaphase I, while others show varying configurations of quadri-, tri-, bi- and univalents. Though the presence of 22 bivalents may suggest an allotetraploid origin, the presence of multivalents in other forms suggests an autotetraploid or segmental polyploid origin. Though the frequency of multivalents is low, it may be considered as an autotetraploid as it is known that the absence or low frequency of multivalents should not be treated as evidence to allopolyploidy (Muntzing and Prakken, 1940; Giles and Randolph, 1951). No definite conclusion can be reached about the nature of the hexaploid form ($2n = 66$) as more detailed study is required of this type. *L. indica* with a very high number ($2n=72$), forms clear 36 bivalents at metaphase I and behaves like a normal diploid. In view of the high number of chromosomes, the normal behaviour at meiosis, profuse fruiting and the existence of lower steps of chromosome numbers (*i.e.*, 36, 48) in this genus suggest that *L. indica* has had an allopolyploid origin.

*Adaptability of various forms.*—Extensive studies on polyploids and their diploid plant forms have shown that each of these types are well adapted to particular ecological conditions and their distribution depends on this factor. *Lantana* grows widely under many types of soil and climatic conditions. The occurrence of numerous polyploid strains may be due to (1) vegetative propagation which affords the possibility of maintenance of even sterile types like triploids and (2) may be in response to particular ecological requirements. As yet no distinct correlation between ecological preferences and chromosome numbers can be drawn. This would require extensive studies in natural habitats. The fact that different types can be grown in ornamental gardens in the same area may be no index for the absence or presence of such a correlation.

*Meiotic behaviour and seed setting.*—As vegetative propagation affords possibility for accumulation of structural changes, irregular meiosis with different associations is common in different *Lantana* types. Certain types, in spite of very irregular meiosis, set fruits while certain other types with regular meiosis form no fruits. It was found

in the present study that there is no correlation between irregularities in microsporogenesis and seed setting in this genus. Detailed studies of controlled pollination, pollen tube growth after hand pollination, and the study of megasporogenesis and embryogeny will show the exact reason for this.

## Summary

A study of the chromosome numbers and their association at meiosis of 22 types of *Lantana* has been made. The chromosome numbers were found to be: (1) *L. camara* var. *mutablis* (which run in euploid series) $2n = 22$, 33, 44, 66. (2) *L. camara* var. *mista* $2n = 44$. (3) *L. camara* var. *crocea* $2n = 22$. (4) *L. camara* var. *nivea* $2n = 22$. (5) *L. camara* var. *sanguinea* $2n = 44$. (6) *L. involucrata* $2n = 36$. (7) *L. lilacina* $2n = 36$. and (8) *L. indica* $2n = 72$. Of these 66, 36 and 72 are new counts for this genus.

There are two groups of *Lantana*, one with a basic number of 11 (*L. camara* group) and another with a basic number of 12 (*L. involucrata*, *L. lilacina*, *L. indica*). While 11 seems to be the primary number of the first group, the chromosome associations at metaphase I suggests a lower basic number for the second group.

The polyploid series with a basic number of 11 was found only in one variety of *L. camara*, *i.e.*, *mutablis*, the other varieties appear to possess a constant chromosome number correlated with certain set characters. The triploid forms ($2n = 33$, 36) appear to be autotriploids because of their high frequency of trivalent formation. Though some tetraploid types ($2n = 44$) form 22 bivalents, others show multivalents at metaphase I, suggesting an autopolyploid or segmental polyploid nature of these forms. *L. indica* ($2n = 72$) which simulates a diploid in its meiotic behaviour appears to have an allopolyploid origin.

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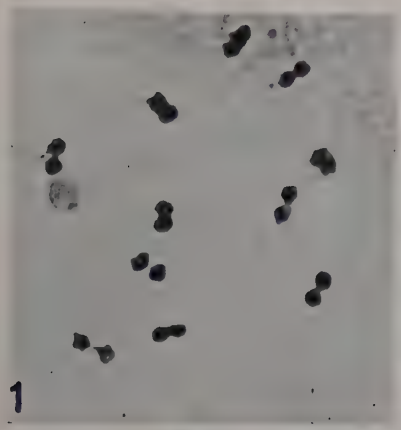


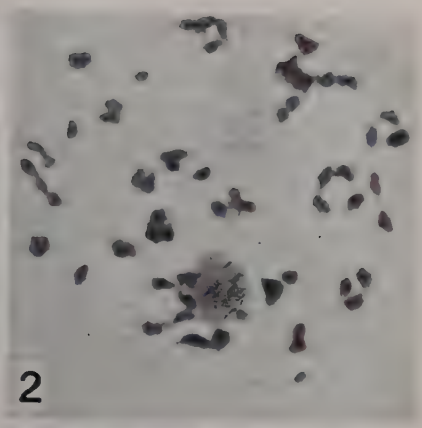


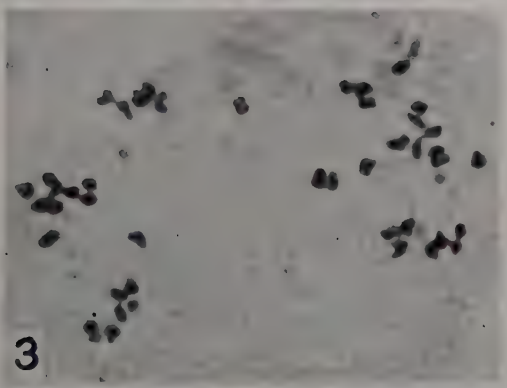


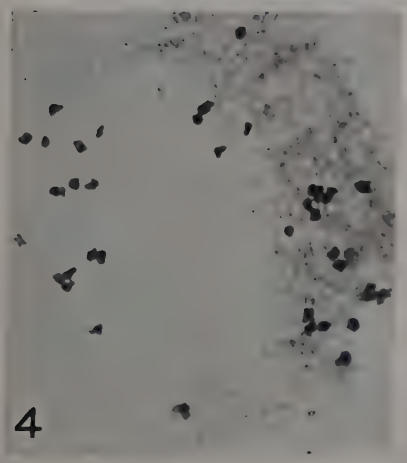


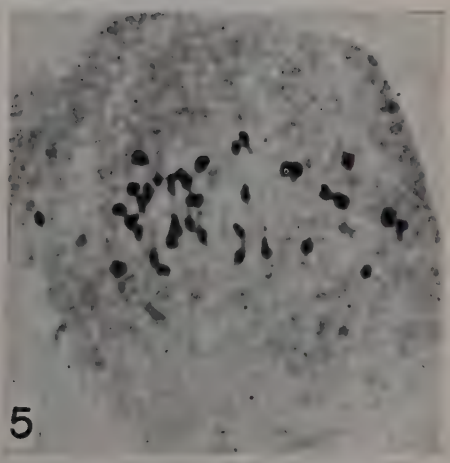


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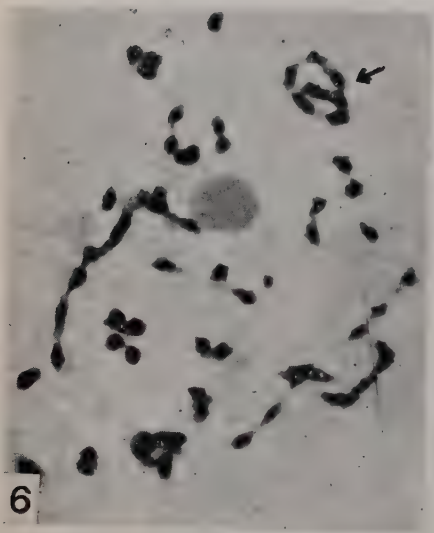


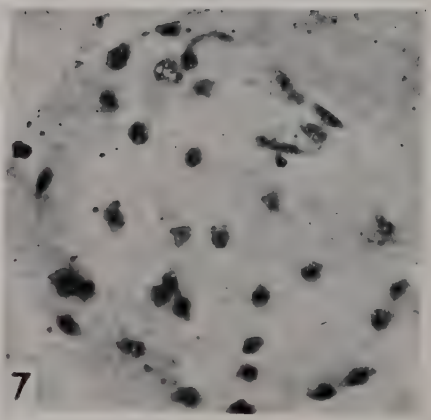


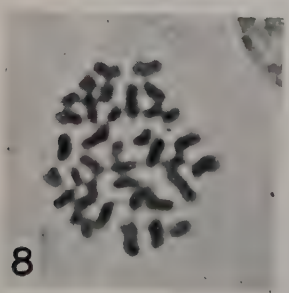


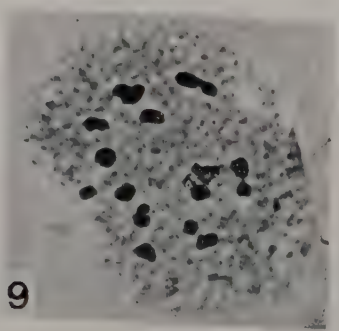


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## EXPLANATION OF PLATES

### PLATE II

FIG. 1. Diakinesis in *L. camara* var. *mutablis*, showing 11 bivalents with one bivalent attached to the nucleolus.

FIG. 2. Diakinesis in hexaploid *L. camara* ($2n = 66$) with the configuration of $V_1$ $IV_3$ $III_8$ $II_{10}$ $I_5$.

FIG. 3. Anaphase I in tetraploid *L. camara* ($2n = 44$).

FIG. 4. Anaphase I in *L. lilacina* ($2n = 36$).

FIG. 5. Early anaphase in *L. involucrata* ($2n = 36$).

### PLATE III

FIG. 6. Diakinesis in *L. camera* ($2n = 66$) showing the formation of heptavalent (arrow).

FIG. 7. Diakinesis in *L. indica* ($2n = 72$) showing 36 bivalents.

FIG. 8. Leaf-tip squash of *L. involucrata* ($2n = 36$).

FIG. 9. Metaphase I of tripolid *L. camara* ($2n = 33$) with the configuration $III_8$ $II_4$ $I_1$.

# CULTURE STUDIES IN THE GENUS *RICCIA* (MICH.) L.

## I. Sporeling Germination in *Riccia billardieri* Mont. *et* N.*

By Ram Udar

*Department of Botany, Lucknow University, Lucknow*

(Received for publication on December 23, 1956)

### Introduction

Sporeling germination in the Marchantiales has been critically reviewed by Mehra and Kachroo (1951), who have also described the germination in *Reboulia hemispherica* (L.) Raddi, *Plagiochasma articulatum* Kash., *P. appendiculatum* L. *et* L., *Mannia* (*Grimaldia*) *indica* (St.), *Asterella blumeana* (Nees), *A. reticulata* (Kash.) Corr. Pandé *et al.*,‡ *A. mussuriensis* (Kash.) Corr. Pandé *et al.*‡ and *A. angusta* (St.) Corr. Mahabale *et* Bhate §. They observed that in the case of all of these the spore ruptures at the tri-radiate mark and the first rhizoid develops from the germ tube and gets separated from the latter by a definite septum. Nearly a year later Mehra and Kachroo (1952) described the spore germination in *Stephensoniella brevipedunculata* Kash. where they observed that the germ tube emerges through the areas between the pentagonal thickenings of the outer face of the spore while the rhizoid is a direct continuation of the germ tube and never gets separated from it by a septum.

In *Riccia* the germination of the spore has been described by Fellner (1875), Campbell (1918), Pandé (1924), Duthie and Garside (1936, 1939), Srinivasan (1940), Abeywickrama (1945) and Venkatachala (1956).

Fellner (1875) described the germination in *R. glauca* without mentioning the exact position in the spore through which the germ tube emerges. According to Campbell (1918) in *R. trichocarpa* the germ tube makes its appearance through the tri-radiate mark which appears to be characteristic of most of the Marchantiales. Pandé (1924), on the contrary, for *the first time observed* that in *R. frostii* Aust. (*R. sanguinea* Kash.) the germ tube arises opposite the tri-radiate mark, *i.e.*, through the outer face of the spore and *through a definite germ pore.* This view has been later supported by Duthie and Garside (1936) who, in a work mainly devoted to the taxonomic aspect, remarked that in all the species studied by them, *viz.*, *R. plana* Taylor, *R. cupulifera* Duthie and *R. curtisii* James, "the spore germinates from the convex outer

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* Contribution from the Department of Botany, Lucknow University, New Series No. 17.

‡ See Pandé *et al.* (1954).

§ See Mahabale *et* Bhate (1945).

face, a peculiarity which has been observed in a number of other South African species, and seems likely to prove constant in the genus". Subsequently Duthie and Garside (1939) observed a similar type of germination in *R. compacta* Garside and *R. rautanenii* St.

Srinivasan (1940) studied the germination stages in a monœcious species of *Riccia*, referred by him as *R. himalayensis* St.**, from sporelings growing in nature but he described fairly advanced stages. As two or more species of *Riccia* grow invariably intermingled in nature it would not be quite safe to rely on the data for a species on this method of obtaining sporelings from the soil unless confirmed by culture studies. He noted, however, that his attempts to germinate the spores in culture met with no success.

Abeywickrama (1945) described the stages of spore germination in *R. crispatula* Mitten from spores sown in water. He observed that an apical cell is established rather early contributing to the tissues of the gametophyte. The first rhizoid is produced relatively late in water cultures but occasionally even before the beginning of the formation of the germ plate.

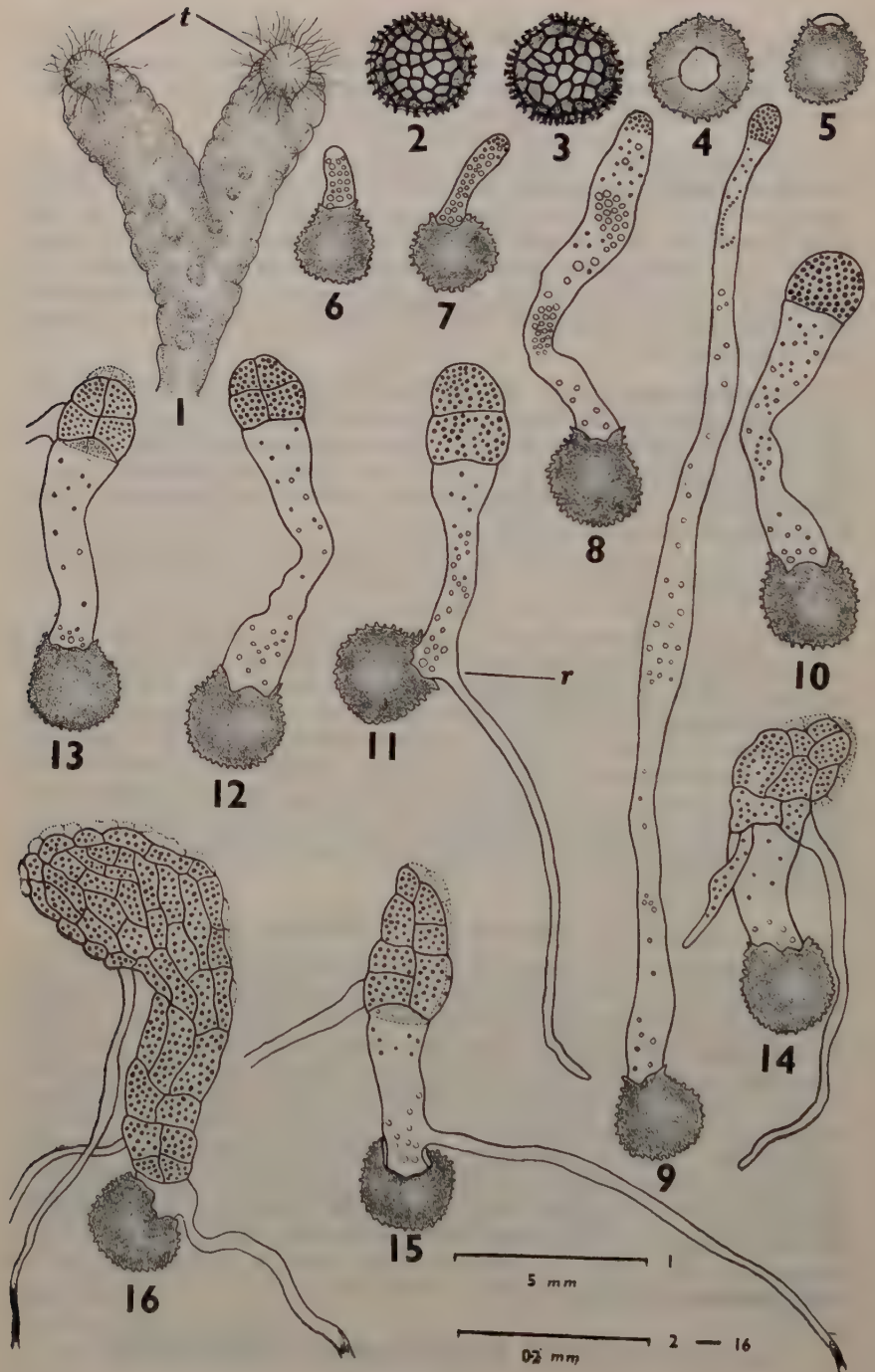
Venkatachala (1956) has figured a single stage of spore germination in *R. discolor* L. *et* L.

In view of the fact that a great deal of confusion persists with respect to the taxonomic limits of several species of *Riccia* growing in India, Dr. S. K. Pandé suggested to the author a detailed investigation of the genus covering all the aspects, *viz.*, taxonomy, cytology and variations in culture to obtain elaborate data to settle the taxonomy of the various species finally. A paper, dealing mainly with critical taxonomic details of *R. discolor*, *R. billardieri* and *R. gangetica* has already been published (Udar, 1957). The present paper deals with the germination of spore of *R. billardieri* and is a part of the culture studies now in progress.

## Material and Methods

*R. billardieri*, a common monsoon species growing in several parts of the country, had long been overlooked and confused with *R. discolor* although it had been reported from India more than half a century back by Schiffner (1900). Both Schiffner (1900) and Stephani (1900) note that this species does not form rosettes though the plants, growing locally, quite often form perfect rosettes. The species is xerophytic but occasionally it may grow even on moist isolated bricks and on walls. The plants are strictly monœcious and the thalli robust and deep green in colour. Conspicuous perennating apical tubers are abundantly developed in this species (Fig. 1, *t*). The spores are reddish-brown, 85–135 $\mu$ in the maximum diameter, reticulate, with 5–8 reticulations across the outer face, the corners of the walls of reticulations project out prominently (Figs. 2, 3).

** See Udar (1957) for the taxonomic status of *R. himalayensis* St.




FIGS. 1–16

FIGS. 1–16. 1. Thallus showing apical tubers, *t*. (ventral view). 2. Spore. 3. Enlarged spore after absorbing moisture. 4. Spore showing a prominent germ pore opposite the tri-radiate mark. 5. Emergence of the germ tube. 6-9. Elongation of the germ tube. 10. Separation of the first cell of the germ plate. 11–15. Further stages of the germlings. *r*., the first rhizoid arising from the germ tube. 16. An advanced germling.

The mature spores of *R. billardieri* were collected from the compound of the local Isabella Thoburn College and the historic Lucknow Residency where it grows luxuriantly. The spores were germinated (*a*) in sterile tap water, on (*b*) 2% Bacto-agar and (*c*) sterilised soil collected from the home locality of the plant. In some cases complete sporophytes, ruptured to expose the spores, were sown. The cultures were made in large glass Petri-dishes covered with glass plates and exposed to diffused light through the north glass window panes of the laboratory. Best result was obtained in (*c*) whereas in (*b*) the spores did not germinate.

## OBSERVATIONS

Apparently spores in *Riccia billardieri* do not require any rest period as fresh collections from the plants of the current year sown on October 5, 1956 germinated in about 6–9 days. In ruptured sporophytes a mass of spores germinated *in situ* showing practically all the stages.

The first sign of germination in the spore is a marked increase in its size (Fig. 3). Subsequently it becomes more or less transparent. This is followed by the appearance of a prominent pore opposite the tri-radiate mark (Fig. 4) as described for *R. forstii* by Pandé (1924). The endospore comes out through this pore in the form of a colourless papilla (Fig. 5) which soon becomes laden with dense contents (Fig. 6). Later a large number of chloroplasts make their appearance (Fig. 7). The germ tube subsequently elongates (Fig. 8). In spores grown in water (Fig. 9) the germ tube elongates considerably but in spores growing on soil, however, it may occasionally remain extremely small (Fig. 16). Due to the inrush of cytoplasm and chloroplasts the apex of the germ tube bulges out conspicuously and shows a deep green colour (Figs. 9, 10). A transverse septum, near the terminal part, delimits the first cell destined to form the germ plate (Fig. 10). Later on this cell divides transversely into two (Fig. 11), each dividing vertically to produce a 4-celled plate (Fig. 12). An older stage showing an 8-celled germ plate is represented in Fig. 13. Subsequently a 2-sided apical cell is established (Figs. 14–16) which cuts off segments adding to the tissues of the gametophyte.

The first rhizoid develops, when the germ plate is 2-celled (Fig. 11, *r*), as a continuation of the germ tube, and is not separated from the latter by a septum (Figs. 11, 15, 16), resembling in this respect *Stephensoniella brevipedunculata* (Mehra and Kachroo, 1952). In *R. trichocarpa*, Campbell (1918) definitely states that the first rhizoid which arises from the germ tube is separated by a septum as in many other Marchantiales. The young rhizoids show granular contents and often even chloroplasts but the latter disappears later.

## Summary

1. In culture the spore of *Riccia billardieri* does not require any rest period and germinates in 6–9 days.

2. Preceding germination the spore enlarges in size and becomes transparent. The germ tube emerges through a prominent pore opposite the tri-radiate mark.

3. The germ tube elongates considerably in spore cultures in water but is much shorter in those grown on soil.

4. An apical call is established in the early stages of the germling contributing to the tissues of the gametophyte.

5. The first rhizoid is a continuation of the germ tube and is not separated by a septum.



## Acknowledgements

Grateful thanks are due to Dr. S. K. Pandé, D.Sc., for suggesting the problem, for his keen interest and guidance in the preparation of the paper and to Dr. E. M. Thillayampalam. Principal, Isabella Thoburn College, Lucknow, for facilities for collecting specimens of *R. billardieri* from the college compound.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* Not seen in original.

# THE PEZIZACEÆ OF THE MUSSOORIE HILLS—I

By K. S. Thind and L. R. Batra

*Botany Department, Panjab University, Amritsar*

(Received for publication on October 19, 1956)

The Panjab University Botany Department has been undertaking a Botanical Excursion each year to the Mussoorie Hills (4,000–7,000 feet altitude in the North-Western Himalayas) under the leadership of Prof. P. N. Mehra, to make a comprehensive study of the Cryptogamic Flora of that region. The taxonomic study of the Pezizaceæ is a part of the Fungal Flora undertaken by Dr. K. S. Thind and his students under that programme.

This interesting and beautiful group of fungi has remained neglected so far in India. Cash (1948) reported five species of Pezizaceæ, of which four are reported from areas now in Pakistan and one from an area in India. Sanwal (1953) reported nine species of Pezizaceæ from India. Previous to these authors there have been only isolated reports of little over one dozen species of Pezizaceæ from different parts of India as listed by Butler and Bisby (1931); Mundkur (1938) and Mundkur and Ahmad (1946). This is very meager treatment of such a large group of fungi. Accordingly, it is our aim to carry on the taxonomic study of Indian Pezizaceæ comprehensively from this laboratory.

This first paper deals with the taxonomy of seven species of Pezizaceæ, all of which are new records in India. The fruit bodies have been described from the fresh material, supplemented with dried material and that preserved in alcohol-formalin.

The numbers of the species are the serial numbers of the Pezizoid Flora.

Type collections have been deposited in the Herbarium of the Panjab University. Duplicate material, in alcohol-formalin, is at the Mycological Collections of the Bureau of Plant Industry, Beltsville, Maryland, U.S.A.

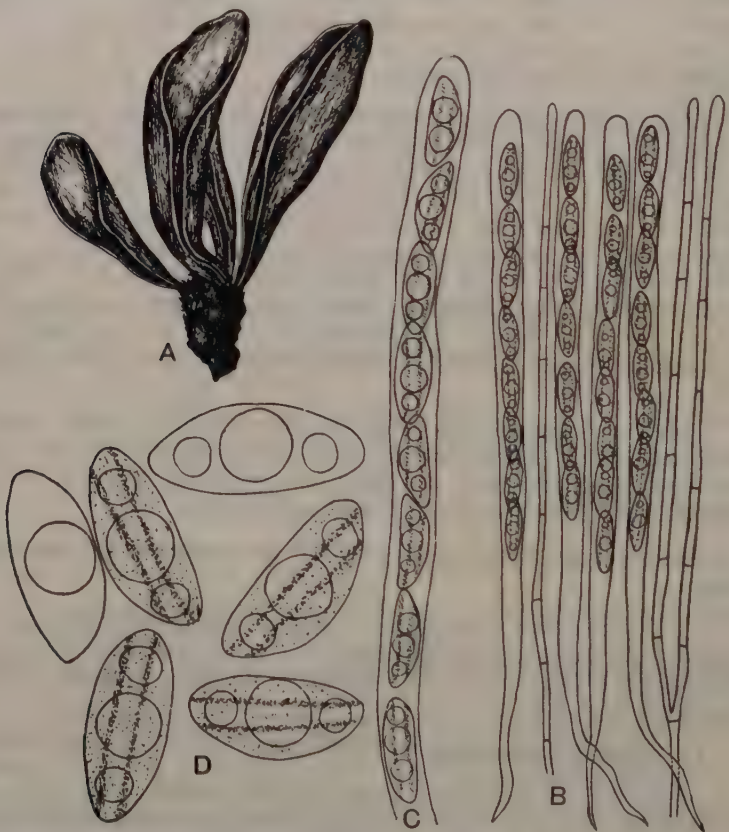
**1. Wynnea americana** Thaxter, *Bot. Gaz.*, **39**: 246, 1905.

*Apothecia* up to 10 cm. long, 3–6 cm. broad, and 2 mm. thick, in scattered cæspitose clusters of 3–12 or more, springing from a common underground sclerotium, dark brown, unsymmetrical, unequal sided, cleft on one side, erect, elongate, ear-shaped, tough or subcoriaceous, thick: sclerotium dark brown, thick, tough, coriaceous, wrinkled, up to 3 cm. long, 1–3 cm. broad, giving off apothecia at the ground level: margin incurved on the cleft side, entire: external surface wrinkled, dark brown, rough due to ectal layer cells projecting

out as fine hair: hymenium dark brown, even, smooth. *Asci* 450–525 × 16–18 μ, elongate, apex rounded, tapering below into a long stem-like base. *Ascospores* 25–35 × 10·5–15 μ, 8 in number, uniseriate, parallel, ends overlapping or not, subhyaline, subcymbiform, unequal sided, *i.e.*, concave on one side and convex on the other, smooth, finely longitudinally striated, ends rounded to pointed or apiculate, guttulate, guttules usually 3 in a longitudinal row, the middle one being the largest. *Paraphyses* 300–500 μ long, 4–5 μ broad at the top, brown, filiform, slightly enlarged at the top, unbranched, septate.

Text-Fig. 1, A–D.

Collected on soil under Oak forest (*Quercus incana* Roxb.), Lal Tibba, Mussoorie, September 18, 1952, **125.**




TEXT-FIG. 1. *Wynnea americana* Thaxter. A. A cluster of apothecia springing from a common undergound sclerotium, × ½. B. Asci and paraphyses, ×200. C. More magnified ascus, ×380. D. Finely longitudinally striated ascospores with 3 guttules, ×880.

The species is characterized by tough, dark brown, thick apothecia springing in cæspitose clusters from a common underground

sclerotium, and large, longitudinally striated, usually 3-guttate ascospores. In the young spores the guttules are very prominent but the striations are hardly detectable. However, in mature spores the striations are well marked but the guttules are not so prominent.

2. **Phillipsia gigantea** Seaver, *North Amer. Cup-fungi*, p. 183, 1928.

*Apothecia* 5–7 cm. in diameter, substance up to 1·5 cm. thick, gregarious, cæspitose consisting of short clusters, shallow cup-shaped, tapering below into a rather thick stem-like base so as to look infundibuliform, stem-like base usually eccentric, fleshy-tough, very thick: margin entire to wavy, not lobed: external surface white, wrinkled: hymenium red, concave. *Asci* 280–300×11–13 $\mu$, cylindrical, apex rounded, gradually tapering below into a long stem-like base, operculum eccentric. *Ascospores* 24–30×9–11 $\mu$, 8 in number but 1–7 spores may be aborted, usually 4 spores aborted, uniseriate, parallel, ends usually not overlapping, subhyaline, subcymbiform, unequal sided, *i.e.*, concave on one side and convex on the other, ends blunt or rounded, smooth, conspicuously longitudinally striated with light and dark bands, guttulate, guttules usually 2, rarely 3, and in a longitudinal row. *Paraphyses* 300–320×3·6 $\mu$, red, filiform, slightly enlarged at the top, unbranched, septate.

Text-Fig. 2, A–D.

Collected on decaying wood of *Shorea robusta* Roxb., Dehra Dun, August 31, 1952, **126.**

This species is easily differentiated by its very thick, cupulate apothecia with a red hymenium and conspicuously longitudinally striated, usually 2-guttate spores. Usually 4, although sometimes as many as 7 spores may be aborted in an ascus of this fungus.

3. **Otidea* leporina** (Batsch ex Fr.) *Fckl. Symb. Myc.*, 329, 1869.
= *Scodellina leporina* (Batsch ex Fr.) S. F. Gray, *Nat. Arrang. Brit.*, Pl. **1**: 668, 1821.

Syn.: *Peziza leporina* Batsch, *Elench. Fung.*, 117, 1783.
*Scodellina onotica* S. F. Gray, *Nat. Arrang. Brit.*, Pl. **1**: 668, 1821.
*Peziza onotica ochracea* Fries, *Syst. Myc.*, **2**: 48, 1822.
*Otidea leporima* Fuckel, *Symb. Myc.*, 329, 1869.

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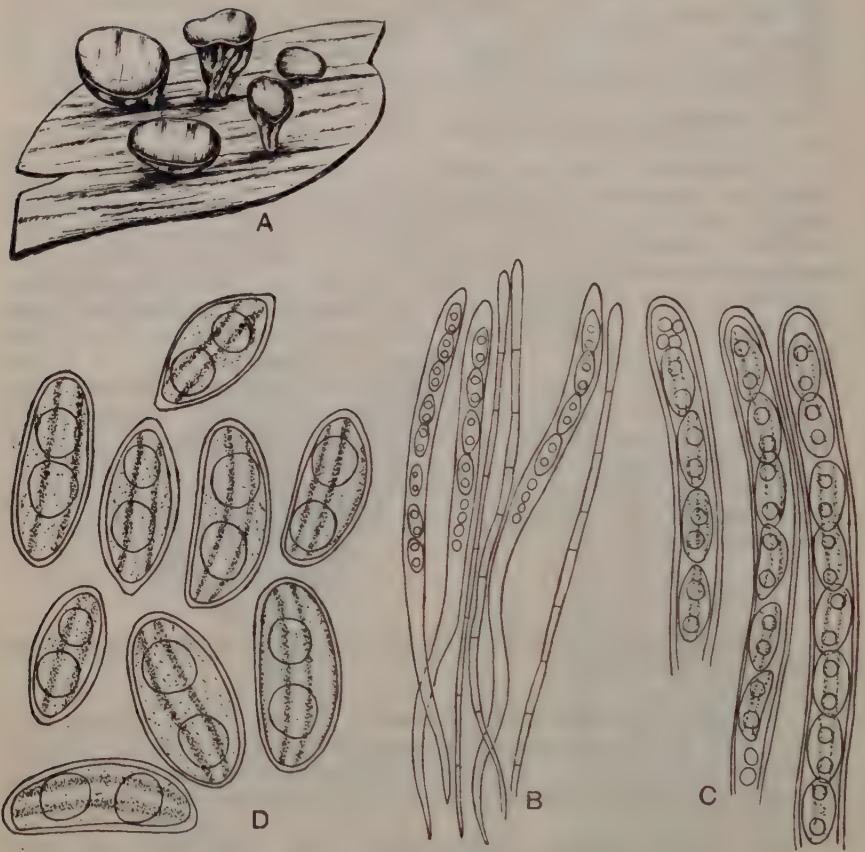
* The generic name *Scodellina* first used by S. F. Gray in 1821 was accepted by Seaver, 1928. Unfortunately, no mention was made of this genus in Fries' *Systema Mycologicum* published in 1822 which, according to the International Rules of Botanical Nomenclature (as adopted by the Cambridge Congress in 1930), is the start of nomenclature of fungi. Thus the name *Scodellina* in untenable as it is pre-Friesian. The genus *Otidea* was established by Fuckel (1869–70) on account of a split in the apothecium. The generic name *Otidea* is in common use and is followed by Kanouse (Studies in the genus *Otidea*. *Mycologia*, **41**: 660–77, 1949) and others.



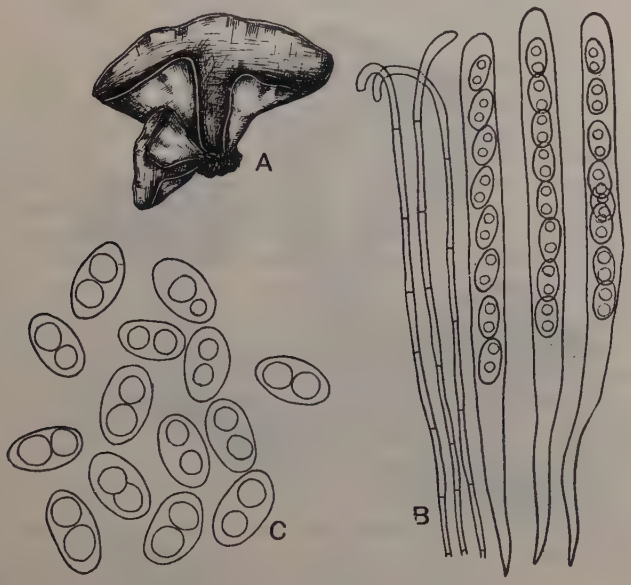

TEXT-FIG. 2. *Phillipsia gigantea* Seaver. A. Apothecia growing on wood, $\times\frac{1}{2}$. B. Asci and paraphyses, $\times 200$. (Note the 4 degenerate spores in 2 asci). C. More magnified asci, $\times 380$. Note 4 and 2 degenerate spores in 2 asci). D. Longitudinally striated ascospores with 2 guttules, $\times 880$.

*Apothecia* 2–5 cm. long and 2–3 cm. broad, gregarious, scattered, or short cæspitose clusters of 2–3, unsymmetrical, cleft on one side, erect, ear-shaped, fleshy, brittle, yellowish brown, substance thin: margin incurved on the cleft side, entire: external surface smooth, yellowish brown: hymenium brown, smooth. *Asci* 173–190×7–8 $\mu$, cylindric to subcylindric, apex rounded, tapering below into a short stem-like base. *Ascospores* 9–14×5–6 $\mu$, 8 in number, uniseriate, parallel to oblique, ends often overlapping, subhyaline, broadly ellipsoid or oblong, with rounded ends, smooth, 2-guttulate. *Paraphyses* 210–235×3–4 $\mu$, brown, filiform, unbranched, strongly curved or hooked at the top, septate.

Text-Fig. 3, A–C.

Collected on soil under Cedrus forest (*Cedrus deodara* Loud.), Lal Tibba, Mussoorie, August 16, 1952, **127**.

The species is marked by unsymmetrical, thin apothecia cleft to the base on one side, oblong and 2-guttate spores, and paraphyses strongly curved or hooked at their apices.




TEXT-FIG. 3. *Otidea leporina* (Batsch ex Fr.) Fckl. A. Cæspitose apothecia cleft to the base on one side, $\times\frac{1}{2}$. B Asci and paraphyses with apices hooked or curved at the top, $\times 200$. C. Biguttulate ascospores, $\times 880$.

4. **Paxina acetabulum** (L. ex. Fr.) Kuntze, *Rev. Gen.*, Pl. **2**: 864, 1891.

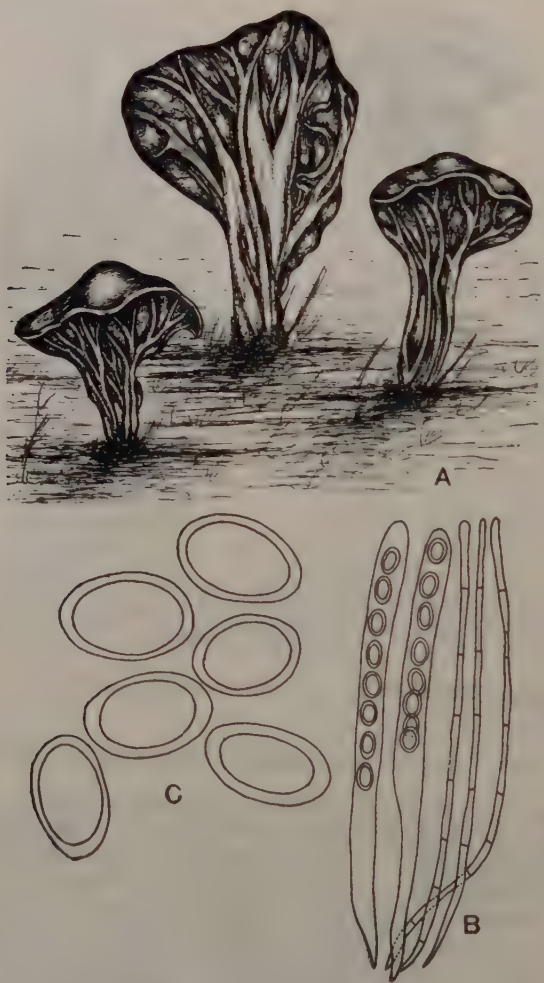
Syn.: *Peziza acetabulum* L. Sp., Pl. 1181, 1753.

*Apothecia* 2–5 cm. in diameter, rarely up to 8 cm. in diameter, 1–3 cm. deep, scattered, gregarious, stipitate, deep cup-shaped, sometimes shallow cupulate, or rarely expanded and almost plane, finely tomentose: margin entire to wavy: external surface milky to grayish white, finely tomentose, strongly ribbed, tomentum composed of fine hairs made up of small, loosely packed, hyaline, drum-shaped cells: hymenium brown to dark brown, smooth, even, concave, rarely plane: stipe $1–5\times 1–1\cdot 5$ cm., milky white, strongly ribbed and lacunose, ribs running up to the margin of the apothecium, solid, thick, expanded above into the apothecium. *Asci* $300–350\times 16–18\,\mu$, cylindrical, apex rounded, gradually tapering below into a short stem-like base. *Ascospores* $16–20\times 10–13\,\mu$, 8 in number, uniseriate, parallel, ends not overlapping, hyaline, broadly ellipsoid to oval, smooth, uniguttulate, guttule

large and filling almost whole of the spore cavity. *Paraphyses* 300–320 $\mu$ long, 3–4 $\mu$ wide at the top, light brown, filiform, unbranched, septate, slightly enlarged at the top.

Text-Fig. 4, A–C.

Collected on soil under coniferous forest, Lal Tibba, Mussoorie, August 29, 1952, **128**.




TEXT-FIG. 4. *Paxina acetabulum* (L. ex Fr.) Kuntze. A. Apothecia with strongly corrugated stipe, the corrugations running up to the margin of the apothecia, ×1. B. Asci and paraphyses, ×200. C. Uniguttulate ascospores, ×880.

The species is easily recognized by its strongly corrugated stipe, corrugations extending up to the margin of the apothecium. All species

of *Paxina* remind one of *Helvella* which, however, does not possess cupulate apothecia. It is of interest to note that Nannfeldt (*Svensk bot. Tidskr.*, **31:** 47–66, 1937) refers *Paxina*, *Leptopodia*, *Macropodia*, etc., all to *Helvella* as synonyms.

5. **Peziza badio-confusa** Korf, *Mycologia*, **46**: 838, 1954.
=*Peziza badia* sensu Seaver.

Syn.: *Peziza badia* Pers. *Obs. Myc.*, **2:** 78, 1799.
*Peziza cochleata* L. Sp., Pl. 1181, 1753.
*Scodellina badia* S. F. Gray *Nat. Arrang. Brit.*, Pl. 1: 669, 1821.

*Apothecia* 3–7 cm. in diameter, gregarious, often crowded together, sometimes scattered, sessile, at first deep cup-shaped, later expanding and becoming shallow cup-shaped, reddish to dark brown, fleshy, very brittle, usually regular, sometimes infolded and cochleate, sometimes also one-sided due to a cleft on one side when it looks like a *Scodellina* species: margin wavy, usually incurved: external surface brown, lighter coloured than the hymenium, rough due to the presence of tubercles or pustules which are small and reddish in colour; hymenium dark brown, smooth, concave. *Asci* 250–300×12–14 $\mu$, cylindrical, apex rounded, narrowed below into a short stem-like base, turning blue with iodine solution. *Ascospores* 16–20×8–10 $\mu$, 8 in number, irregularly arranged when young, later uniseriate, parallel to oblique, ends overlapping or not, subhyaline or pale brown, ellipsoid, broadly rounded at the ends, verrucose, warts coarse, prominent and 1·5 $\mu$ long, short and incomplete ridges also present on the spore wall, uniguttate, guttule large and filling three-fourth of the spore cavity. *Paraphyses* 200–250 $\mu$ long, up to 7 $\mu$ wide at the top, brown filiform, unbranched, septate, enlarged at the top.

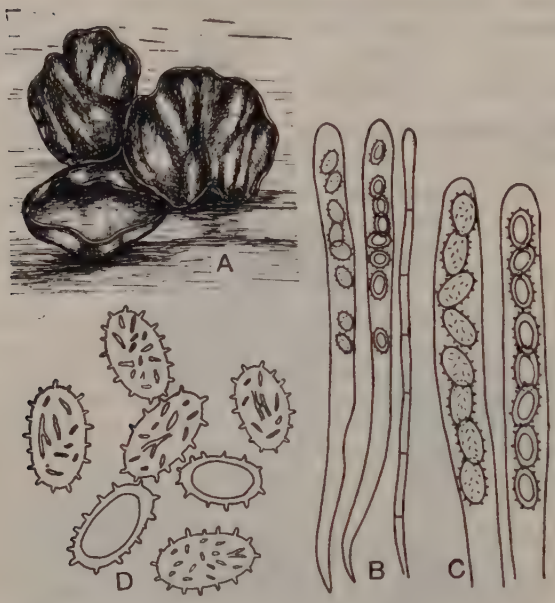
Text-Fig. 5, A–D.

Collected on charcoal preparation beds under Oak forest, Jabber Khet, Mussoorie, August 29, 1952, **129**.

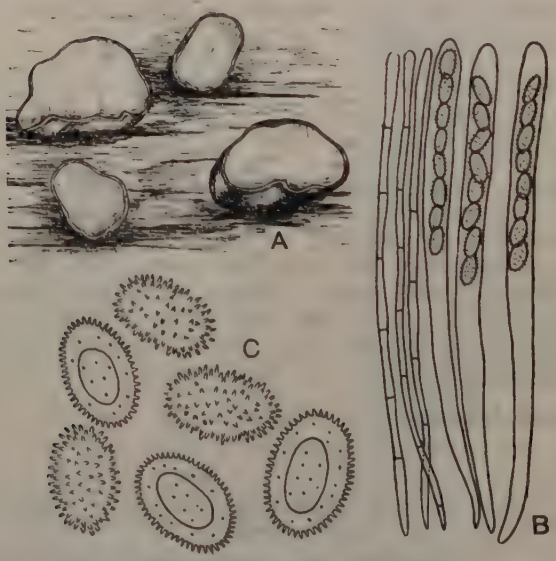
The spores of this fungus are broadly rounded at the ends and not strongly narrowed at the ends as reported by Seaver, 1915. It has been established by Le Gal (*Rev. Mycol.*, **2**: 205–207, 1937) that *Peziza badia* Pers. has reticulate, not verrucose spores. The species described and illustrated by many other authors, including Seaver, has been renamed by Korf (*Mycologia*, **46**: 838, 1954) as *P. badio-confusa* Korf. Boudier (*Hist. Class. Discom. Eu.*, 48, 1907) illustrates the spores as broadly rounded at the ends, not narrowed as in Seaver's illustration.

6. **Peziza brunneoatra** Desm., *Ann. Sci. Nat.* II, **6**: 244, 1836.

Syn.: *Aleuria brunneoatra* Gill., *Champ. Gr. Discom.*, 53, 1879.
*Plicaria brunneoatra* Rehm. in *Rab. Krypt. Fl.*, **1³**: 1010, 1896.
*Galactinia brunneoatra* Boud., *Hist. Class. Discom. Eu.*, 49, 1907.




TEXT-FIG. 5. *Peziza badio-confusa* Korf. A. Apothecia, ×1. B. Asci and paraphyses, ×200. C. More magnified asci, ×380. D. Verrucose, uniguttulate ascospores, ×880 (Note also the short, incomplete ridges on the spore-wall).




TEXT-FIG. 6. *Peziza brunneoatra* Desm. A. Apothecia, ×1. B. Asci and ascospores, ×200. C. Prominently and densely verrucose ascospores, ×880.

*Apothecia* 1–2 cm. in diameter, up to 1 cm. deep, scattered, gregarious, or closely crowded together, at first deep cup-shaped, later expanded and shallow cup-shaped to discoid, sessile, regular, sometimes contorted due to mutual pressure, fleshy, brittle: margin entire, tubercled: external surface brown to dark brown, rough due to minute tubercles: hymenium slightly darker than the external surface, smooth, concave to plane. *Asci* 253–300×12–16 $\mu$, cylindrical, apex rounded, tapering below into a short stem-like base, turning blue with iodine solution. *Ascospores* 15·8–19·3×7–11 $\mu$, 8 in number, uniseriate, usually oblique, ends usually overlapping, subhyaline, broadly ellipsoid, ends broadly rounded, densely verrucose, warts prominent and up to 1·5 $\mu$ long, 1–2 guttulate. *Paraphyses* up to 300×4·5 $\mu$, up to 9 $\mu$ wide at the top, subhyaline, clavate, simple, enlarged at the top, septate.

Text-Fig. 6, A–C.

Collected on soil, Balharu Khad, Mussoorie, August 23, 1952, **130.** On soil, Sri Kunth, Mussoorie, September 11, 1954, **131.**

This species is differentiated from *Peziza badio-confusa* Korf by the smaller apothecia and the absence of ridges on the spore walls.

7. **Peziza succosa** Berk., *Ann. Mag. Nat. Hist.*, I, **6**: 258, 1841.

Syn.: *Aleuria succosa* Gill., *Champ. Fr. Discom.*, 45, 1879.
*Otidea succosa* Thüm., *Mycoth. Univ.*, 1411, 1879.
*Galactinia succosa* Sacc., *Syll. Fung.*, **8**: 106, 1889.
*Plicaria succosa* Rehm. in *Rab. Krypt. Fl.*, **1**$^{3}$: 1016, 1896.

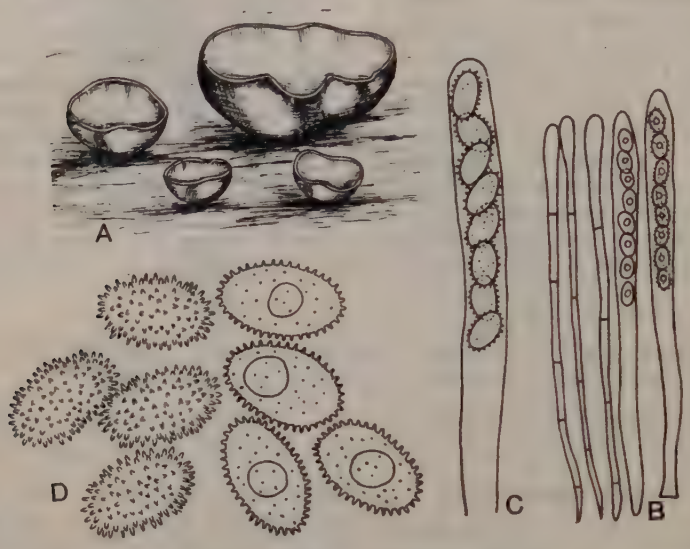
*Apothecia* 3–4 cm. in diameter, gregarious, sessile, milky white, at first deep cup-shaped, later expanding and shallow cup-shaped, fleshy, brittle, flesh when broken turning yellow, regular, sometimes contorted, sometimes apothecia proliferate forming a cupulate structure in their middle which is sterile from within and fertile from outside, *i.e.*, the two hymenia are continuous; margin entire to wavy: external surface milky white, smooth: hymenium smoky brown, smooth, concave. *Asci* 260–300×10–14 $\mu$, cylindrical, apex rounded, tapering below into a short stem-like base, turning blue with iodine solution. *Ascospores* 16–20×8–12 $\mu$, 8 in number, uniseriate, parallel, sometimes oblique, hyaline, usually broadly ellipsoid, ends broadly rounded, conspicuously and profusely verrucose, warts small, uniguttulate, rarely 2-guttulate, guttule small and filling about one-fourth of the spore cavity, guttule very conspicuous in young spores. *Paraphyses* 250–300 $\mu$, up to 10 $\mu$ wide at the top, subhyaline, filiform, unbranched, septate, considerably enlarged at the top.

Text-Fig. 7, A–D.

Collected on soil under a mixed forest (Oak and Pine), The Park, Mussoorie, July 31, 1952, **132.**

This species is characterized by its flesh, when broken, turning yellow, and prominently verrucose, spores. The spores in Mussoorie

collection are uniguttulate, rarely 2-guttulate, whereas *Peziza succosa* Berk. is reported to have usually 2-guttulate spores (Seaver, 1928).




TEXT-FIG. 7. *Peziza succosa* Berk. A. Apothecia, ×1. B. Asci and paraphyses with much enlarged tops, ×200 (Note the young spores in one ascus are smooth-walled). C. More magnified ascus, ×380. D. Prominently and profusely verrucose spores with one small guttule, ×880.

## ACKNOWLEDGEMENTS

The authors are deeply indebted to Miss Edith K. Cash of U.S. Department of Agriculture, Beltsville, Maryland, for help in the identification of the species and valuable suggestions and Prof. P. N. Mehra for encouragement and facilities. They are also thankful to Mr. B. Khanna for making illustrations of the fructifications.

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# HYPHOMYCETES—III*

## Two New Genera, *Dwayaloma* and *Sadasivania*

By C. V. Subramanian

*University Botany Laboratory, Madras-5*

(Received for publication on December 15, 1956)

I propose to describe in this paper two interesting fungi recently collected by me from the Nilgiris, Madras State.

48. **Dwayaloma trina** gen. et sp. nov.

This fungus was collected by me on dead culms and leaves of an unidentified grass from the Sim's Park, Coonoor, Nilgiris. The fungus forms distinct and conspicuous colonies on the substratum. The colonies are superficial, black, velutinous, scattered, separate or sometimes confluent, of variable size, circular to elliptical in outline, up to about 5 mm. in diameter, and setose. The colonies are composed of a thin, superficial stratum of subhyaline to brown, polygonal cells from some of which the setæ are produced. The setæ are sterile, simple, erect, mostly straight, sometimes bent, dark brown below, paler above, thick-walled, long-subulate, non-septate, swollen at the base, and pointed or somewhat blunt at the tip; they are 72–180 $\mu$ long, 6·0–9·1 $\mu$, wide at the swollen base and 4·2–5·6 $\mu$ wide immediately above. The conidia are produced acrogenously and singly directly on sporogenous cells which are intermixed with the setæ. The conidia are cylindrical to oblong with rounded ends, hyaline, transversely one-septate in the middle, smooth-walled, 19·6–22·4 $\mu$ long, 7·0–8·4 $\mu$ wide, and each with a somewhat flat to slightly concave, distinct basal scar about 1·5 $\mu$ wide indicating the point of attachment to the sporogenous cell. The mature conidium has one appendage each at the apex and at the base, the basal one always arising a little away from the point of attachment of the conidium to the sporogenous cell. Each appendage (*i.e.*, the apical and the basal ones) is forked once, 2–3 $\mu$ above the point of its origin; the branches are filiform, thin, hyaline, each of variable and not necessarily of equal length, about 1 $\mu$ wide and 28–42 $\mu$ long in the mature spore. The sporogenous cells are simple, one-celled, subhyaline to pale brown in colour, 7·0–9·8 $\mu$ tall and 4·2–5·6 $\mu$ wide. Immature conidia have only the apical appendage, the lower one being absent; the latter is obviously developed later. Mature conidia always have both the appendages.

The striking features of the fungus are: (i) the characteristic hya'odidymospores, each with one terminal and one basal appendage, each of which is forked once immediately above the point of its origin;

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* Hyphomycetes I and II were published in this Journal, **35**: 53–91 and **35**: 446–94 respectively.

(ii) the production of these spores acrogenously and singly directly on simple sporogenous cells; (iii) the presence of dark brown stiff sterile setæ intermixed with the sporogenous cells; and (iv) the entirely superficial nature of the colonies.

The fungus is best classified as a simple Dematiaceous hyphomycete. In the Dematiaceæ, it may be placed in the group of fungi which produce sterile setæ intermixed with conidiophores—genera such as *Beltrania*, *Lacellina*, *Lacellinopsis*, *Circinotrichum*, *Helicotrichum*, *Sarcopodium*, etc. However, the characteristic appendaged hyalodidymospores distinguish it from all genera of the hyphomycetes so far known and I, therefore, propose a new genus for it. The generic and specific names are both derived from Sanskrit: the generic name *Dwayaloma* from द्वय (*dwaya*) = two-fold, pair, and लोम (*loma*) = hair, indicative of the two hair-like spore appendages each of which is divided into two; and the specific epithet *trina* from त्रिण (*trina*) = grass, indicative of the substratum (grass) on which it was collected.

**Dwayaloma** Subramanian gen. nov.

Pertinet ad Fungos Imperfectos, ad Moniliales, Dematiaceas Didymosporas.

Coloniæ superficialiæ, constantes e strato tenui cellularum subhyalinarum vel brunnearum, quæ cellulas sporogenas producunt setis intermixtas. Setæ erectæ, simplices, brunneæ, rigidæ, subulatæ. Cellulæ sporogenæ simplices, subhyalinæ ad brunneas. Conidia cylindrico-oblonga, hyalina, semel septata, acrogene producta atque singulariter e cellulis sporogenis; unumquodque conidium appendici et basali et apicali ornatum; appendix vero semel fissa in duos ramulos hyalinos, filiformes, longos supra ipsam basim.

Fungus imperfectus, Moniliales, Dematiaceæ, Didymosporæ.

Colonies superficial, composed of a thin stratum of subhyaline to brown cells producing sporogenous cells intermixed with setæ. Setæ erect, simple, brown, stiff, subulate. Sporogenous cells simple, subhyaline to brown. Conidia cylindrical-oblong, hyaline, one-septate, produced acrogenously and singly directly on sporogenous cells; each conidium with one basal and one apical appendage; each appendage forked into two hyaline, long, filiform branches immediately above its point of origin.

Type species:

**Dwayaloma trina** Subramanian sp. nov.

Coloniæ superficiales, dispersæ, disjunctæ vel confluentes, nigræ, sericæ, circulares vel ellipticæ ambitu, usque ad 5 mm. diam., constantes e cellulis sporogenis intermixtis setis. Setæ et cellulæ sporogenæ emergunt e strato tenui, superficiali et basali cellularum; cellulæ subhyalinæ vel brunneæ, polygonales. Setæ steriles simplices, erectæ, ut plurimum

rectæ, aliquando curvæ, fusce brunneæ infra, pallidiores supra, crassis parietibus præditæ, longo-subulatæ, haud septatæ, tumescentes ad basim, acutæ vel plus minus hebetes ad apicem, 72–180 $\mu$ longæ, 6·0–9·1 $\mu$ latæ ad basim tumescentem, 4·2–5·6 $\mu$ latæ supra ipsam basim. Conidia cylindrico-oblonga, apicibus utrisque rotundis, hyalina, semel septata, levia, 19·6–22·4 $\mu$ longa, 7·0–8·4 $\mu$ lata, producta acrogene et singulariter e cellulis sporogenis, appendiculata, singula cicatrice basali aliquantum concava vel plana 1·5 $\mu$ lata ornata. Appendices conidiales singulæ ad utrumque apicem conidii, semel fissæ ca. 2–3 $\mu$ supra ipsam basim, ramuli vero filiformes tenues, hyalini, longitudinis variæ nec necessario constantis, ca. 1 $\mu$ lati, 28–42 $\mu$ longi.

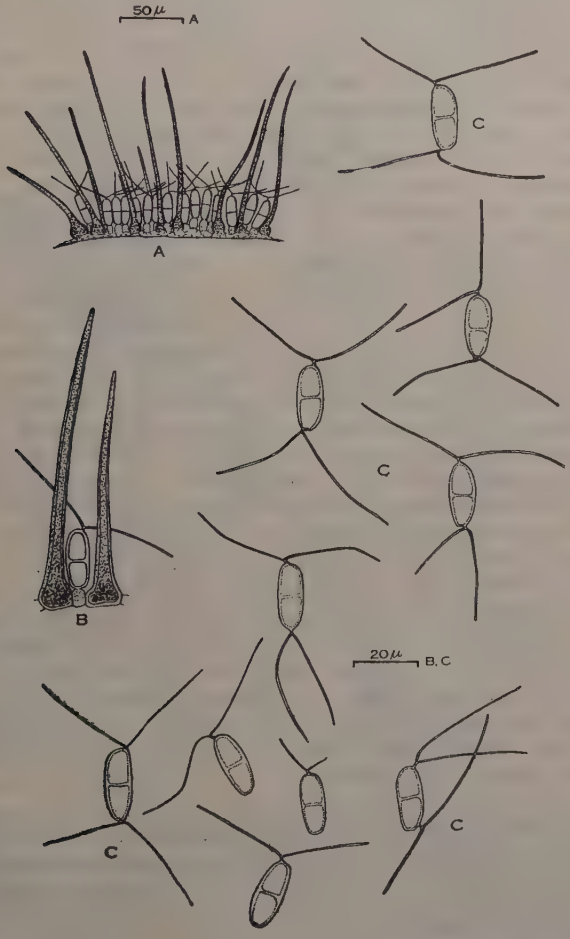


FIG. 1. *Dwayaloma trina* from type specimen, Herb. M.U.B.L. 1670. A, section of a colony showing the thin basal stratum of cells, setæ and conidia borne on sporogenous cells; B, two setæ and a sporogenous cell bearing one conidium; C, mature and immature conidia: note that the immature conidia lack the basal appendage.

Typus lectus in culmis emortuis et foliis graminis cuiusdam in loco Sim's Park, ad Coonoor, Nilgiri District in Statu Madras, die 22 mensis novembris anni 1956 a C. V. S. et positus in Herb. M.U.B.L. sub-numero 1670.

49. **Sadasivania girisa** gen. et sp. nov.

This is another interesting fungus which was recently collected by me from the Nilgiris, also on dead leaves of Gramineæ. The colonies on the substratum are dark brown to blackish in colour, effuse and consist of scattered groups of conidiophores with conspicuous heads of conidia, occurring singly or in small groups. The capitate heads of conidia are dark brown to blackish in colour, mostly globose to subglobose, and 210–350 $\mu$ in diameter. The conidiophore consists of a main stipe which is unbranched, erect, straight, sometimes bent, stout, thick-walled, cylindrical, dark brown, non-septate, conspicuously swollen at the base which may be embedded in the substratum, and fertile only towards the apex. The stipe is up to 460 $\mu$ long, 32·4–43·2 $\mu$ wide at the swollen base, and 14·4–18·0 $\mu$ wide above. The fertile terminal part of the stipe is 90–108 $\mu$ long and 18–20 $\mu$ wide. The conidia are produced on sporogenous cells. The sporogenous cells are produced in chains from the fertile part of the stipe. Numerous such chains of sporogenous cells arise from the fertile part of the stipe and when the spore-bearing chains of these sporogenous cells are shed, tattered parts of the basal cells in the chains or scars are left on the stipe. These scars are 5·6–7·7 $\mu$ in diameter. The sporogenous cells have a characteristic shape, being subglobose to turbinate or shortly-clavate, somewhat rounded in the upper half and obconical in the lower half. They are finely verrucose, conspicuously darkened and thickened in the lower half and, in sudden contrast, thin-walled and hyaline to subhyaline in the upper half. The mature sporogenous cells are 7·0 $\mu$ wide and 5·6–6·1 $\mu$ long. The sporogenous cells form simple or sometimes branched acropetal chains of variable length, but often up to 200 $\mu$ long. The conidia are produced singly from usually one to three, often up to four, points on the lower darkened and thickened halves of all sporogenous cells in a chain, and also singly and terminally on the apical sporogenous cell alone of a chain. The production of one to four conidia from different points on the basal part of each sporogenous cell of a chain results in a regular aggregation of conidia around the chain, simulating a bunch of grapes, and each bunch has a diameter of 18·0–25·2 $\mu$. These bunches resemble the aggregations of conidia around the subhyaline conidiophores so characteristic of species of *Arthrinium*. Indeed, the head of conidia is composed of numerous such simple or branched bunches of conidia borne on the fertile part of the stipe. The mature conidia are one-celled, globose, dark brown, conspicuously verrucose to sub-spinous, thick-walled and 7–10 $\mu$ in diameter.

The fungus is easily classified in the Dematiaceæ-Amerosporæ. In general appearance and structure, *e.g.*, the production of capitate heads of conidia on unbranched conidiophores, my fungus has

a close similarity to *Periconia* and, indeed, it was originally disposed by me under that genus. However, careful study has revealed certain features peculiar to my fungus. In contrast to species of *Periconia*, in my fungus the conidia are always produced singly and never in chains. The sporogenous cells are very distinct from the conidia functionally and morphologically, and usually form simple

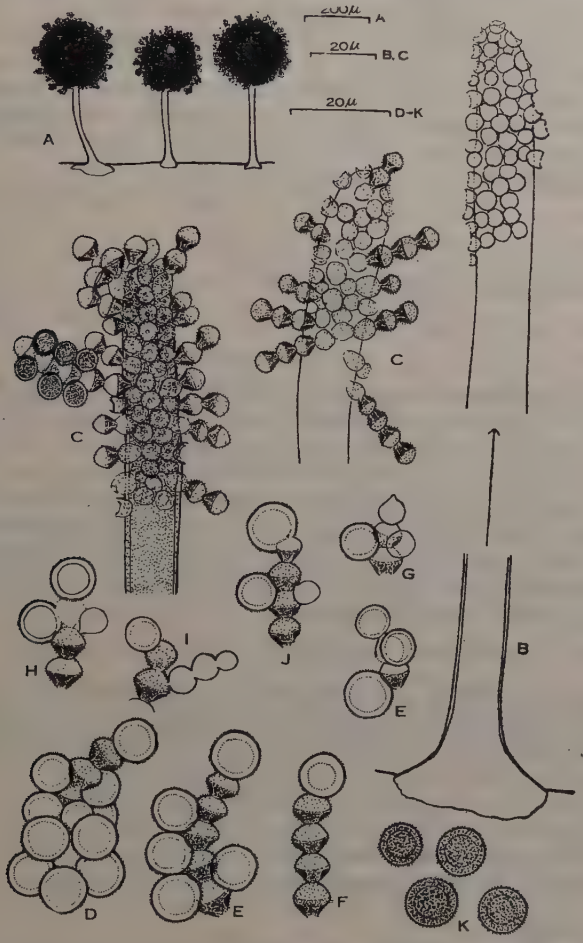


FIG. 2. *Sadasivania girisa* from type specimen, Herb. M.U.B.L. 1671. A, conidiophores bearing globose heads of conidia; B, enlarged drawing of conidiophore showing the apical fertile portion from which the conidia (and chains of sporogenous cells) have been shed; C, apical fertile part of the conidiophore showing origin and production of chains of sporogenous cells bearing conidia; D, part of a cluster of conidia borne on sporogenous cells; E, part of chains of sporogenous cells showing points of attachment of conidia; F, part of a chain of sporogenous cells, with one terminal conidium on the apical sporogenous cell; G, showing acropetal development of chains of sporogenous cells; H, I, showing development of branched acropetal chains of sporogenous cells; J, showing development of conidia; K, mature conidia.

acropetal chains; branching of these chains, whenever present, is also acropetal. The conidia are produced only from the thickened basal halves of the sporogenous cells, except in the case of the terminal sporogenous cell of each chain on which they are also produced terminally. This method of spore formation results in regular bunches of conidial aggregations around chains of sporogenous cells and numerous such distinct bunches compose the head of conidia. I know of no genus among the hyphomycetes having all the characteristics of my fungus and I, therefore, propose to classify it in a new genus, *Sadasivania*, named after Professor T. S. Sadasivan of Madras, as a humble tribute to one who first encouraged me to study hyphomycetes and, indeed, initiated me in the study of fungi. The specific epithet, *girisa* is from Sanskrit गिरिश = dwelling in the mountains, indicative of the occurrence of the fungus in the Nilgiris at an elevation of over 7,000 feet above sea-level.

**Sadasivania** Subramanian gen. nov.

Pertinet ad Fungos Imperfectos, ad Moniliales, Dematiaceas Amerosporas.

Coloniæ constantes e conidiophoris dispersis et capitulis conidialibus. Conidiophori constant e stipite principali, haud ramoso, ad apicem fertili. Cellulæ sporogenæ simplices, emergentes e parte fertili stipitis, ad maturitatem crassæ et fuscæ in inferiore dimidia parte, tenuibus parietibus præditæ supra, efformantes catenulas simplices vel furcatas et acropetas. Conidia unicellulata, globosa, brunnea, producta singulariter e punctis non-nullis in parte basali tumescenti uniuscuiusque cellulæ sporogenæ, atque etiam terminaliter ex uno puncto in cellulis sporogenis apicalibus catenularum.

Fungus imperfectus, Moniliales, Dematiaceæ, Amerosporæ.

Colonies composed of scatterred conidiophores with heads of conidia. Conidiophore consisting of a main, unbranched stipe, fertile towards the apex. Sporogenous cells simple, arising from fertile part of stipe, when mature, thickened and darkened in the lower half, thin-walled above, forming simple or branched acropetal chains. Conidia one-celled, globose, brown, produced singly from several points on the basal thickened half of every sporogenous cell, and also terminally from one point on apical sporogenous cells of the chains.

*Type species:*

**Sadasivania girisa** Subramanian sp. nov.

Coloniæ fusce brunneæ vel nigrescentes, effusæ, constantes ex acervis dispersis conidiophororum, conidiorum capitulis conspicuis. Capitula conidialia fusce brunnea vel nigrescentia, subglobosa vel globosa, 210–350 $\mu$ diameter. Conidiophori vel stipites simplices, erecti, recti, aliquando curvati, robusti, crassis parietibus præditi, cylindrici, fusce brunnei, non-septati, tumescentes ad basim, fertiles ad apicem, usque ad 460 $\mu$ longi, 32·4–43·2 $\mu$ lati ad basim tumescentem,

14·4–18·0 μ lati supra; stipitis portio apicalis fertilis 90–108 μ longa, 18–20 μ lata. Cellulæ sporogenæ simplices, emergentes e parte stipitis fertili, formæ typicæ, subglobosæ vel turbinatæ ad breviter clavatas, pulchre verrucosæ, 7·0 μ latæ, 5·6–6·1 μ longæ; rotundatæ, tenuibus parietibus præditæ et hyalinæ vel subhyalinæ in superiore dimidia parte; aliquantum obconicæ, fuscæ et conspicue crassæ in inferiore dimidia parte; efformantes catenulas simplices vel ramosas acropetas usque ad 200 μ longas. Conidia producta singulariter generatim ex 1–3, sæpe 1–4, punctis in parte inferiore crassa singularum cellularum sporogenarum in catenula; atque etiam singulariter et terminaliter ex puncto uno cellulæ sporogenæ apicalis in catenula; conidia matura unicellulata, globosa, fusce brunnea, conspicue verrucosa vel subspinosa, crassis parietibus prædita, diametientia 7–10 μ.

Typus lectus in foliis emortuis graminis cuiusdam in loco Hortu Gubernii, ad Ootacamund, Nilgiri Distri., in Statu Madras, die 19 mensis novembris anni 1956 a C. V. S. et positus in Herb. M.U.B.L. sub numero 1671.

The fungus was first collected on the same substratum and from the same locality by Prof. Sadasivan and myself on December 9, 1953 (Herb. M.U.B.L. 997), but the material was meagre.


## Summary

Two new genera of the hyphomycetes are described in this paper, both based on material collected on dead culms and leaves of Gramineæ from the Nilgiris, Madras State, India: (i) *Dwayaloma* (Dematiaceæ. Didymosporæ) based on the type species, *D. trina*; and (ii) *Sadasivania* (Dematiaceæ. Amerosporæ), with the type species, *S. girisa*.



## Acknowledgement

I am deeply indebted to the Rev. Father Dr. H. Santapau for kindly translating the diagnoses of the new genera and species into Latin.

# *NEOTTIOSPORA* DESM. AND TWO NEW GENERA, *SAMUKUTA* AND *SAKIREETA*

By C. V. Subramanian and K. Ramakrishnan

*University Botany Laboratory, Madras-5*

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The genus *Neottiospora* was described by Desmazières in 1843 with *N. caricum* Desm. as the type species (Desmazières, 1843). His diagnoses of the genus and the type species were as follows:—

"Neottiospora, Nob. Char. gen. Perithecium immersum, latitans, sphæricum, membranaceum, ore orbiculari apertum. Nucleus gelatinosus, subcirrhose expulsus. Ascis nullis. Sporidiis fusiformibus, filis 3, 4, tenuissimis terminalibus ornatis. Sporulis globosis.

"18. Neottiospora Caricum, Nob.

N. amphigena. Peritheciis sparsis, minutis, ferrugineis, demum umbrinis, in parenchymate folii nidulantibus, epidermide nigrifacto tectis; ore integro nigro. Cirrhis crassis, aurantiaceis: sporidiis minutissimis, subhyalinis; sporulis 3–4, vix distinctis.

Hab. in foliis siccis Caricum variarum."

In a discussion following the diagnosis, Desmazières stated: "Le caractère essentiel de ces sporidies est de présenter, à l'une des extrémités, trois ou quatre filamens d'une tenuitè extrême, simples ou bifurqués, divergens, quelquefois même un peu recourbés, et moitié environ moins longs qu'elles" (Desmazières, 1843, p. 347).

Desmazières placed his genus in the Pyrenomycetes; however, it is obviously an imperfect fungus producing the spores within pycnidia and was, therefore, compiled in the Sphæropsideæ-Sphærioideæ-Hyalosporæ by Saccardo (1884, p. 216). In his key to the genera, Saccardo (1884, p. 3) characterised the spores of *Neottiospora* as "ovato-fusoideæ, apice penicillo-setosæ". Saccardo's classification and his characterisation of the genus have been followed by many later workers (Lindau, 1900; Allescher, 1901; Migula, 1921; Clements and Shear, 1931).

As far as we are aware, besides the type species, twelve species have been described in *Neottiospora* since the genus was established by Desmazières. They are listed below in chronological order:—

1. *N. gigaspora* Fuckel 1867.
2. *N. coprophila* Spegazzini 1879.
3. *N. paludosa* Sacc. & Fiori 1899.
4. *N. longiseta* Raciborski 1900.
5. *N. schizochlamys* Ferd. & Winge 1908.

6. *N. lycopodina* Hoehnel 1909.
7. *N. arenaria* Sydow 1912.
8. *N. yuccæfolia* Hall 1915.
9. *N. theæ* Sawada 1915.
10. *N. philippinensis* Diedicke 1916.
11. *N. oryzæ* Hara 1918.
12. *N. laserpitii* Bres. 1926.

In 1919 Hoehnel made brief observations on some species of *Neottiospora* (Hoehnel, 1919 *a*) and these observations were discussed in greater detail by him in a paper which appeared in 1924 posthumously (Hoehnel, 1924). After studying type material, Hoehnel pointed out that *Sphæria caricina* Desm. (Desmazières, 1836) is an earlier name for *Neottiospora caricum* Desm. and accordingly proposed the combination, *Neottiospora caricina* (Desm.) Hoehnel for the fungus. Hoehnel further stated that Desmazières' characterisation of the pycnidiospores as having three to four apical cilia was wrong. On the other hand, according to him, the conidium lacks apical appendages; when the conidium gets detached, part of the conidiophore remains persistent and attached to the base of the conidium and this remains hanging as a wrinkled, and often conically broadened, tattered membrane. The nature of the conidial appendages in *Neottiospora paludosa*, *N. arenaria* and *N. schizochlamys* was considered by Hoehnel to be similar, but quite differently formed from that of *N. caricina*. In these species, according to Hoehnel, the cell membrane of the conidium is composed of three layers of which the middle one swells and the outermost layer consequently breaks off finally and is completely absent below but is firm at the apex being attached to the inner membrane and later splits twice or thrice longitudinally; as a result, a few streak-like upwardly directed flaps which simulate cilia remain at the tip as a crown. Hoehnel pointed out that the nature of these spore-appendages was similar to that of *Tiarospora perforans* (Rob.) Hoehnel (= *Sphæria perforans* Rob.), the type species of the genus *Tiarospora* Sacc. & March. (Hoehnel, 1919 *b*); however, *Tiarospora* which belongs to the Sphæropsidales-Sphærioideæ has phæodidymospores, whereas *Neottiospora paludosa*, *N. arenaria* and *N. schizochlamys* produce hyalospores. Hoehnel, therefore, proposed a new genus *Tiarosporella* to accommodate these species. His diagnosis of *Tiarosporella* was as follows:—

"Fruchtkörper derbwandig, parenchymatisch, rundlich, eingewachsen, nicht vorbrechend, ohne vorgebildetes Ostiolum, oben sich durch Ausbröckeln rundlich öffnend. Konidienraum einfach. Trager kurz. Konidien gross, keulig-zylindrisch, mit dreischichtiger Zellhaut. Mittelschichte verquellend, Aussenschichte in 2–3 Längsstreifen zerreissend, die nach obenhin zurückgeschlagen werden und Cilien vortäuschen. Pseudosphæriale Nebenfrüchte" (Hoehnel, 1924, pp. 82–83.)

The type species was stated to be *Tiarosporella paludosa* (Sacc. & Fiori) Hoehnel (= *Neottiospora paludosa* Sacc. & Fiori). *N. schizochlamys* was transferred to *Tiarosporella* as a second species, *T. schizo-*

*chlamys* (Ferd. & Winge) Hoehnel, and *Neottiospora arenaria* Sydow was considered by Hoehnel to be a synonym of this species.

Clements and Shear (1931) recognised the genus *Tiarosporella* and cited *T. paludosa* as the type species; but Hoehnel's (1919 *a*, 1924) interpretation of the spore-appendage in *Neottiospora* was not followed and, in their key to the genera of the Sphæropsidales, they characterised the conidia of *Neottiospora* as many-ciliate at the apex. What is more, they included conidia of *N. arenaria* Sydow (drawn from Sydow, No. 1124) as being typical of the genus (Clements and Shear, 1931, Plate 49, Fig. 7 *b*), although, as we pointed out earlier, this species was classified in *Tiarosporella* by Hoehnel.

Curiously enough, Hoehnel (1923) omitted *Tiarosporella* from his System of Fungi imperfecti, although *Neottiospora* was included in the Sphæropsidales-Sphærioideæ-Ostiolatæ and its hyalospores were described merely as "mit Cilien", without any definite indication of the position or the nature of these cilia !

In a work on British Sphæropsidales by Grove (1935), Hoehnel's (1919 *a*, 1924) interpretation of the spore-appendage in *Neottiospora* was again not followed. Grove (*loc. cit.*, p. 134) suggested that the conidia of *Neottiospora* are "provided at the apex with a tuft of little mucoid setæ which readily disappear" and his figures indicate the presence of distinct and separate cilia.

Recently, Bessey (1950) characterised the conidia of *Neottiospora* as having "several early disappearing apical appendages".

Thus, Hoehnel's (1919 *a*, 1924) interpretation of the spore-appendage in this genus was not followed by the few workers who have discussed this little known group of imperfect fungi.

More recently, Arnaud (1952, p. 221) in a contribution on Fungi imperfecti, described pycnidiospores of *Neottiospora* as: "Spores non-pourvus de cilas a la base, mais d'un appendice an entonnoir irregulierement decoupe en franges" and classified the genus in the Zythiaceæ.

In 1953 we published a short paper (Subramanian and Ramakrishnan, 1953) on the nature of the spore-appendage in *Neottiospora* after studying type material of *N. caricina* (cited as *N. caricum*), although, unfortunately, we were not then aware of Hoehnel's interesting work (Hoehnel, 1919 *a*, 1924) and Arnaud's (1952) observations. Contrary to Hoehnel's interpretation, we suggested that in *Neottiospora* there is only one appendage for the spore and that it is apical; that the appendage is mucoid and evanescent, and that it is in the form of an inverted hollow cone with hyaline thin walls. We also indicated that the development of the spore may be as follows: "During the development of the spore, the outermost wall (or layer of the wall ?), being inelastic, splits transversely along a line just below the middle of the spore due to the elongation of the body of the spore. The spore itself then gets detached from the conidiophore and the upper portion of the outer

wall which has split is now seen as a cap enclosing the spore down to more than half its length. This thin cap later gets everted and this then appears as a hyaline, inverted hollow cone with very thin walls. It is obvious that the outer side of the cap which originally enclosed part of the spore now forms the inner side of the hollow cone" (Subramanian and Ramakrishnan, 1953, p. 229). It is clear that this is somewhat similar to what was described for the genus *Tiarosporella* by Hoehnel, although he did not state that the appendage was mucoid and evanescent. We have made a careful study of the type and other material of *Neottiospora caricina*, after we read Hoehnel's (1924) paper, but we are not able to confirm his interpretation of the spore-appendage in this species. In our opinion, the conidium of *N. caricina* does have an apical appendage and this is mucoid and evanescent and formed of the broken outermost membrane of the spore wall which gets everted sooner or later. Further, the development of, and the nature of, the spore-appendage in *N. paludosa*, *N. schizochlamys* and *N. arenaria* are very similar to those of *N. caricina*, although the appendage, and the spore itself, are larger and more conspicuous in the former three species than in *N. caricina*. We, therefore, consider that *N. paludosa*, *N. schizochlamys* and *N. arenaria* are indeed congeneric with *N. caricina* and propose that *Tiarosporella* Hoehnel be reduced to synonymy with *Neottiospora* Desm.

NEOTTIOSPORA Desm. char. emend.

Desmazières, 1843, *Ann. Sci. nat., Bot.*, **19:** 346.

Synonym: *Tiarosporella* Hoehnel, 1919, *Ber. dtsch. bot. Ges.*, **37:** 159; Hoehnel, 1924, *Mitt. bot. Lab. tech. Hochsch. Wien*, **1:** 82.

Fungus imperfectus, Sphæropsidales, Sphærioideæ, Hyalosporæ.

Pycnidia separate, globose, membranous, dark coloured, ostiolate. Conidiophores short, simple, hyaline. Pycnidiospores hyaline, one-celled, produced acrogenously and singly at the tips of conidiophores, each with an apical appendage. Appendage mucoid, evanescent, in the form of an inverted hollow cone with hyaline, thin walls; formed by the rupture of the outer spore wall which later gets everted and takes a funnel-like appearance.

*Type species*

*Neottiospora caricina* (Desm.) Hoehnel, 1919, *Ber. dtsch. bot. Ges.*, **37 :** 158; Hoehnel, 1924, *Mitt. bot. Lab. tech. Hochsch. Wien*, **1 :** 78.

≡ *Sphæria caricina* Desm., 1836, *Ann. Sci. nat.*, Bot., **6 :** 246.

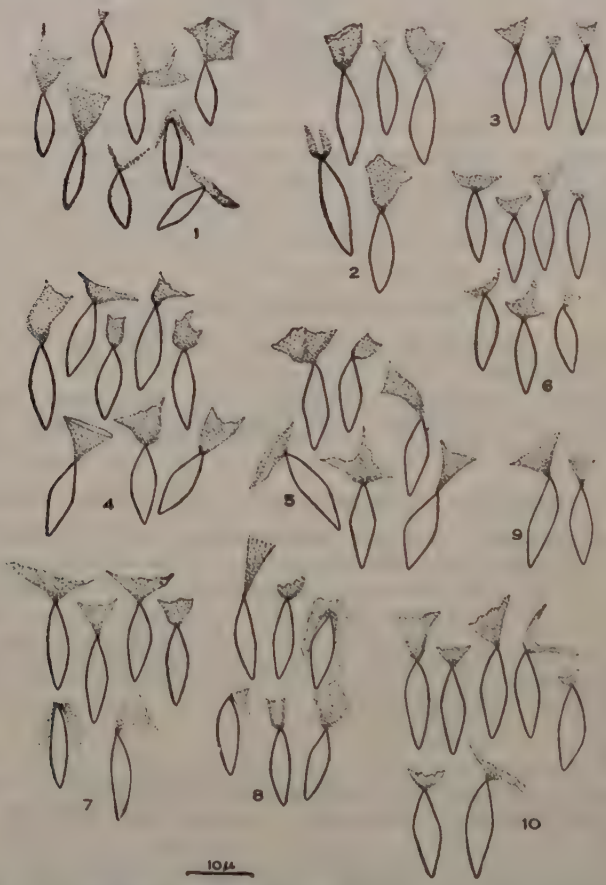
= *Neottiospora caricum* Desm., 1843, *Ann. Sci. nat.*, Bot., **19 :** 346.

≡ *Darluca caricum* (Desm.) Fuckel, 1869, *Symb. Mykol.*, p. 380 (Fungi rhenani No. 1723).

Grove (1935) cites *Zythia maxima* Fautrey, 1896 (*Rev. mycol., Toulouse*, 1896: 71) as a synonym, but we have not verified this.

*Description*

Pycnidia amphigenous, separate, scattered, small, brownish black, immersed, globose, membranous, 300–400 $\mu$ in diam., ostiolate; ostiole distinct, round. Pycnidiospores fusiform, thin-walled, smooth, hyaline, one-celled, each with an apical appendage. Appendage membranous, mucoid, evanescent, in the form of an inverted hollow cone with hyaline, thin walls or a cap covering the upper part of the spore. Spores 12·8–16·0 × 3·2 $\mu$, appendage 8 × 6·4 $\mu$ (in TYPE).




FIGS. 1–10. Pycnidiospores of *Neottiospora caricina*, from Herb. M.U.B.L. 689, 690, 692, 694, 695, 697, 876, 877, 880 and 881 respectively. For details, see text.

*Specimens examined*

1. *Neottiospora* nob. not. gen. 1338 *Neottiospora caricum*, not. *Sphæria caricina* not. no. 717. Hab. in foliis siccis *Caricum variarum*.

Plantes Cryptogames de France. Par J. B. H. J. Desmazières, Fungi of France, ex Herb. nat. Hist. Mus., Paris; also ex Herb. New York bot. Gdn. and U.S.D.A. (M.U.B.L. 690)—TYPE.

2. *Neottiospora caricum* Desm. ad folia exsiccata Caricis pendulæ Cæn Coll. Roberge, Fungi of France, ex Herb. New York bot. Gdn. (M.U.B.L. 692).

3. *Neottiospora caricum* Desm. on *Carex pendula*, Somersetshire, Jan. 7, 1850, C. E. Broome (comm.) H. W. R. (avenal), ex Herb., New York bot. Gdn. (M.U.B.L. 693).

4. *Neottiospora caricum* Desm. on *Carex maxima*, Bois a montier, St. Jean. 9 Jan. 1897. Herbies cryptogamique de la Cote-d'Or (France) par F. Fautrey, Fungi of France, 1621, ex Herb. New York bot. Gdn. (M.U.B.L. 694).

5. *Neottiospora caricum* Desm. Vercellis: ex eunte nejeune. Cesati, Fungi of Italy, 1893, ex Herb. New York bot. Gdn. (M.U.B.L. 695).

6. *Neottiospora caricum* Desm., Bohemia sept.: Teplitz in *Caricum div.* sp., foliis aridis, vere 1872 ipse legi de Thuemen, fungi austriaci (Fungi of Bohemia) 680 ex Herb. New York bot. Gdn. (M.U.B.L. 696).

7. *Neottiospora caricum* Desm. fol. Caricis. Herb. W. R. Gerard 628. Fungi of France, ex Herb. New York bot. Gdn. (M.U.B.L. 697).

8. *Neottiospora caricum* Dz.. Batheaston, Somerset, 1851, C. E. Broome ex Herb. R.B.G. (M.U.B.L. 876).

9. *Neottiospora caricum* Desm. Rudloe, Wiltshire, C. E. Broome, ex Herb. M. J. Berkeley ex Herb. R.B.G. (M.U.B.L. 877).

10. *Neottiospora caricum* Desm. ad folia sicca Caricum pendulæ oc ripariæ ex Herb. Mougeot & Nestler, Stripes Cryptogamieæ 1263, ex Herb. R.B.G. (M.U.B.L. 880).

11. *Neottiospora caricum* Desm. Desmazières 1350, sur des feuilles seches de *Carex pendula*, Caen., Normandy, France, leg. Roberge ex Herb. R.B.G. (M.U.B.L. 881).

12. *Neottiospora caricina* Hoehn. ad folia putrida Caricis pendulæ in moute Georgenberg prope Punkersdorf, in silva Wienes Wald, M. Mart. (adsunt etiam alii fungi). leg. C. Keisler Krypt, Exs. ed a Mus. Hist. Nat. Vindobon (Fungi of Austria) 3032 ex Herb. New York bot. Gdn. (M.U.B.L. 689).

Measurements of conidia and their appendages for these twelve collections are given on next page.

This indicates the variability seen in different collections: the pycnidiospores may be 10·2–17·0 $\mu$ long and 2·1–4·8 $\mu$ wide. The length and maximum width of the funnel-shaped appendages of the spores also vary. They may be 3·4–12·6 $\mu$ tall and 2·5–11·9 $\mu$ where

| No. in Herb. M.U.B.L. | Conidia | | Appendage | |
|---|---|---|---|---|
| | Length μ | Breadth μ | Length μ | Breadth μ |
| 690 TYPE | 12·8–16·0 | 3·2 | 8·0 | 6·4 |
| 692 | 11·9–15·3 | 3·4–4·1 | 5·1 | 6·8 |
| 693 | 12·6–14·0 | 2·8–4·2 | 4·2 | 8·4 |
| 694 | 11·1–15·3 | 2·5–3·4 | 8·5–10·2 | 5·1–10·2 |
| 695 | 11·9–17·0 | 2·5–4·1 | 6·8– 8·5 | 3·4– 8·5 |
| 696 | 12·6–14·7 | 2·8–4·2 | 4·2 | 8·4 |
| 697 | 10·2–16·2 | 2·5–3·4 | 3·4– 5·1 | 2·5– 5·1 |
| 876 | 12·6–14·0 | 2·1–3·5 | 8·4– 9·8 | 5·6–11·2 |
| 877 | 11·2–15·4 | 2·8 | 5·6–12·6 | 2·8– 5·6 |
| 880 | 12·8–16·0 | 3·2–4·8 | 6·4 | 6·4 |
| 881 | 14·4–16·0 | 3·2 | 4·8–11·2 | 6·4– 9·6 |
| 689 | 10·2–13·6 | 2·5–3·4 | 7·6– 8·5 | 2·5–11·9 |

they are widest. The appendage is always thin, flimsy, mucoid and membranous and, as observed by Grove (1935), may not be visible in very old and ill-preserved material.

It is also clear that the species is confined to species of *Carex* (Cyperaceæ).

One collection labelled "*Neottiospora caricum* Desm. var. with large brown spores, Spye Park, Wiltshire, C. E. Broome, Jan. 1850, ex Herb. M. J. Berkeley", ex Herb. R.B.G. (M.U.B.L. 878), has also been studied. The specimen consists of a very small fragment of a leaf about 5 cm.×2 mm. with four pycnidia. The pycnidia are dark, immersed in the substratum, have membranous walls, and are up to 400 μ in diam. The conidia are large, mostly elliptical in shape, often with a slightly mamillate base, smooth, dark brown, one-celled, and 12·8–17·6×3·2–4·8 μ. Each spore has an apical appendage which is evanescent, mucoid and of the nature of an inverted hollow cone with hyaline, thin walls. This appendage is 6·4–11·2 μ tall and 9·6–19·2 μ wide. It is formed in the same way as in *Neottiospora caricina*.

In recording this collection, Berkeley and Broome (1850, p. 379) stated: "A variety occurs with larger olive coloured spores, which we should at once have considered distinct, but for specimens in which the spores, though olive coloured, without any orange tinge, are exactly of the same size as in the original form. We do not, therefore, venture at present to consider the two as distinct, though we think it probable that further observations may justify their separation." Grove (1935) also mentioned it and obviously considered it a variety of *N. caricina*, following Berkeley and Broome.

However, the dark coloured brown spores separate it from *N. caricina* and related species of this hyalospored genus. It cannot, therefore, be retained in *Neottiospora*. It appears to be similar to *Tiarospora perforans* (Rob.) Hoehnel, the type species of the genus *Tiarospora* Sacc. & March. (Hoehnel, 1919 *b*) with one difference, *viz.*, *T. perforans* has phæodidymospores, whereas Broome's Spye Park collection sub *Neottiospora caricum* has phæospores (one-celled). Broome's collection, therefore, cannot be classified either in *Neottiospora* or in *Tiarospora*. Indeed, we know of no other genus in which it can be appropriately classified and we propose a new genus for it. The generic name *Samukuta* is derived from Sanskrit: सह (*saha*) = with, and मुकुट (*mukuta*)= tiara, diadem, indicative of the apical tiara-like appendage of the spore. The specific epithet *berkeleyii* is after the late Rev. M. J. Berkeley, well known for his contributions to British mycology.

**Samukuta** Subramanian and Ramakrishnan gen. nov.

Fungus imperfectus, Sphæropsidales, Sphærioideæ, Phæosporæ.

Pycnidia separate, globose, membranous, dark coloured, ostiolate. Conidiophores short, simple. Pycnidiospores dark brown, one-celled, produced acrogenously and singly at the tips of conidiophores, each with an apical appendage. Appendage mucoid, evanescent, in the form of an inverted hollow cone with hyaline, thin walls.

Pertinet ad Fungos Imperfectos, ad Sphæropsidales, Sphæroideas, Phæosporas.

Pycnidia disjuncta, globosa, membranacea, fusce colorata, ostiolata. Conidiophori breves, simplices. Pycnidiosporæ fusce brunneæ unicellulatæ, acrogene productæ atque singulariter ad apices conidiophororum, singulæ præditæ appendice apicali. Appendix mucoidea, evanescens, coni inversi vacui instar, parietibus hyalinis et tenuibus præditi.

Species typica sequens.

**Samukuta berkeleyii** Subramanian and Ramakrishnan sp. nov.

Pycnidia fusca, dispersa, separata, immersa, nonnihil globosa, parietibus membranaceis, usque ad 400 $\mu$ diam. Conidiophori simplices. Pycnidiosporæ ellipsoideæ, leves, fusce brunneæ, unicellulatæ, 12·8–17·6 × 3·2–4·8 $\mu$, singulæ appendice apicali præditæ. Appendix mucoidea, evanescens, coni inversi vacui instar parietibus hyalinis et tenuibus, effo:mata per disruptionem muri exterioris sporarum, qui postea evertitur et infundibuliformis evadit, 6·4–11·2 $\mu$ alto, 9·6–19·2 $\mu$ lata.

Typus lectus in Carice quodam (?) in Spye Park, Wiltshire, mense januario 1850 a C. E. Broome ex Herb. M. J. Berkeley in Herbario Kewensi, Kew (M.U.B.L. 878).

OTHER SPECIES

2. *Neottiospora paludosa* Sacc. & Fiori apud Sydow, 1899, *Hedwigia*, **38** : 137.

   = *Tiarosporella paludosa* (Sacc. & Fiori) Hoehnel, 1919, *Ber. dtsch. bot. Ges.*, **37** : 159; Hoehnel, 1924, *Mitt. bot. Lab. tech. Hochsch. Wien*, **1** : 83.

Saccardo and Fiori (apud Sydow, 1899) described the fungus as follows: "Peritheciis late et densiuscule gregariis, parallele seriatis, globulosis $\frac{1}{6}$–$\frac{1}{8}$ mm.; innatis, nigris, glabris, vix ostiolo punctiformi erumpentibus; contextu distincte parenchymatico fuligineo; sporulis oblongo-cylindraceis, utrinque rotundatis, rectis curvulisve, subsessilibus, 35–45 × 4–6 $\mu$, granuloso-guttulatis, hyalinis, apice filamentis binis initio sporulæ appressis, dein erectis, 25–40 × $1\frac{1}{2}$ $\mu$, undulatis, curvisve, hyalinis coronatis. Hab. in foliis emortuis v. languidis *Eriophori polystachyi*, Zehlendorf pr. Berolinum."

We have seen type material of this fungus which is labelled: "*Neottiospora paludosa* Sacc. & Fiori n. sp. in foliis emortuis v. languidis Eriophori polystachyi. Zehlendorf pr. Berolinum. 10. 1895. leg. P. Sydow, Sydow, Mycotheca marchica (Fungi of Germary) 4842" ex Herb. New York bot. Gdn. (M.U.B.L. 698). The leaf fragments of the type material are small bits up to 1 cm. long and have about 20–25 pycnidia per sq. cm. of leaf tissue where the pycnidia are gregarious. The pycnidia are separate, black, and deeply immersed in the leaf tissue. In section, they appeared to be subglobose to pyriform with a thick, dark brown, parenchymatous wall and a definite ostiole. Hoehnel's (1924) observation that the pycnidia are without typical ostioles could not be confirmed. The spores are large, subcylindrical or more often narrowly clavate, tapering below to a smooth, rounded base, and gradually becoming broadened and smoothly rounded at the apex where they are broadest, hyaline, smooth, 24–49 $\mu$ long and 4·1–8·5 $\mu$ wide where they are widest. Each spore has one apical appendage. This appendage is mucoid, more conspicuous than that of *Neottiospora caricina*, and may sometimes form a somewhat transparent cap covering the upper one-third or more of the spore; or, it might split into distinct flaps and lie closely appressed to the wall of the spore, as was described by Saccardo and Fiori; in yet other cases, the broken flaps may spread out and then appear as distinct and separate appendages. The appendages are 8·3–13·3 $\mu$ long. There is no doubt that the appendages are formed as in *N. caricina* and, as already indicated, we consider the fungus a good *Neottiospora*.

The species does not appear to have been collected as frequently as *N. caricina* and no collections, other than the type, have been seen by us.

3. *Neottiospora schizochlamys* Ferdinandsen and Winge, 1908, *Svensk bot. Tidskr.*, **28**: 255, *ic.*; Saccardo, 1913, *Sylloge Fungorum*, **22**: 929.

= *Tiarosporella schizochlamys* (Ferdinandsen and Winge) Hoehnel, 1919, *Ber. dtsch. bot. Ges.*, **37 :** 159; Hoehnel, 1924, *Mitt. bot. Lab. tech. Hochsch. Wien*, **1 :** 83.

= *Neottiospora arenaria* Sydow, 1912, *Ann. mycol.*, **10 :** 448; Saccardo, 1931, *Sylloge Fungorum*, **25 :** 184.


FIGS. 11–17. Fig. 11. Pycnidiospores of *Neottiospora paludosa* from type specimen, Herb. M.U.B.L. 698; Fig. 12. Pycnidiospores of *N. arenaria* from type specimen, Herb. M U.B.L. 708; Fig. 13. Pycnidiospores of *N. schizochlamys* from type specimen, Herb. M.U.B.L. 707; Fig. 14. Pycnidiospores of *Samukuta berkeleyii* from type specimen, Herb. M.U.B.L. 878; Figs. 15–17. *Sakireeta madreeya* from type specimen, Herb. M.U.B.L. 631: Fig. 15. Section of pycnidia; Fig. 16. Part of pycnidium in section showing pycnidial wall, conidiophores and spores; Fig. 17. Pycnidiospores.

*Neottiospora schizochlamys* was described as follows: "Peritheciis immersis, papillo erumpentibus, globosis vel subglobosis, contextu parenchymatico, circ. 250 μ diam., nigris, seriatis. Conidiis cylindraceis, vel cylindraceo-clavatis, utrinque rotundatis, plasmate irregulariter

partito, nebuloso, subsessilibus, primitus gelatino indutis, dein membrano gelatinoso longitudinaliter fisso, apice (2?—) 4-ciliatis, 24–37 $\mu$ $\times$6–7½ $\mu$, sæpe curvatis, hyalinis. Appendiculis 1 $\mu$ crassit, longitudine sporarum, primo sporis adpressis, dein erectis, corniformibus, hyalinis, mox evanescentibus. Ad caules siccos Scirpi cæspitosi prope Borris Jutlandiæ." Ferdinandsen and Winge added: "The species described is most clearly related to *N. paludosa* Sacc. & Fiori (upon *Eriophorum*, Berlin). The genus is connected with Cyperaceæ and it is probable that the peculiar appendix is a sort of floating apparatus" (Ferdinandsen and Winge, 1908, pp. 255–56).

We have seen type material of this fungus which is labelled: "*Neottiospora schizochlamys* Ferd. & Winge on *Scirpus cæspitosus*, Tylland: Borris, May 27, 1906, leg. et det. Ferdinandsen and Winge", ex Herb. U.S.D.A. (M.U.B.L. 707). The material consists of two small bits of leaf with about 15 pycnidia in one and five in the other. The pycnidia are visible to the naked eye, separate, black and about 0·25 mm. in diam.; they are somewhat globose, parenchymatous and largely immersed in the substratum. The pycnidiospores are elongate, cylindrical or more often slightly clavate being widest towards the apex and narrowest towards the base, hyaline, smoothly rounded at the tip, and each with an evanescent, mucoid appendage at the tip; they are 23·1–39·1 $\mu$ long and 5·1–8·3 $\mu$ wide. The appendage appears either as flaps closely appressed to the apical part of the spore or may be directed away from the spore wall or even directed upward and is 6·6–16·6 $\mu$ long. Indeed, the nature of the spore-appendage and its development are very similar to those of *Neottiospora caricina* and *N. paludosa*. *N. schizochlamys*, therefore, is a good *Neottiospora* and is retained in the genus in this paper.

Hoehnel (1919 *a*, 1924) indicated that *N. arenaria* Sydow is a synonym of *N. schizochlamys*.

*N. arenaria* was described by Sydow as follows: "Peritheciis dense sparsis, haud seriatim dispositis immersis, epidermide parum vel vix atrata tectis, globosis, 110–175 $\mu$ diam., atris, glabris, vix ostiolo punctiformi erumpentibus; contextu distincte parenchymatico, fusco, subopaco, ex cellulis inæqualibus 10–17 $\mu$ diam. composito; sporulis oblongo-cylindraceis, vel subfusiformibus, rectis, utrinque obtusis, sæpe guttulatis, continuis, hyalinis, 22–35$\times$5½–8 $\mu$, ad apicem filamentis 2–3 initio sporulæ appressis, dein erectis vel sæpius divergentibus, 20–32 $\mu$ longis ca. 1–1½ $\mu$ latis, hyalinis flexuosis vel varie curvis, distinctissimus ornatis, basidiis brevissimis hyalinis suffultis. Hab. in folliis emortuis Caricis arenariæ. Sperenberg pr. Zossen, 16–5–1912, leg. H. Sydow" (Sydow, 1912, p. 448; Saccardo, 1931, p. 184).

We have examined the type collection which is labelled: "*Neottiospora arenaria* Sydow on *Carex arenaria*, Brandenburg, Sperenberg bei Zossen, 5·16·12. coll. H. Sydow", ex Herb. U.S.D.A. (M.U.B.L. 708) which is the same as Sydow, Mycotheca germanica 1124 which we have seen ex Herb. R.B.G. The pycnidia are black, somewhat globose,

separate, immersed, parenchymatous in texture, and up to 280 $\mu$ in diam. The spores are subcylindrical to clavate, with smooth walls, hyaline, widest towards the apex which is rounded, one-celled, and straight or curved. A few spores were seen with apical appendages and it is clear that the specimen has not been preserved well. The appendage is mucoid and evanescent and appeared mostly as a shallow cap at the tip of the spore. The conidia are 28·0–36·4 $\mu$ long and 4·9–7·0 $\mu$ wide.

Clements and Shear (1931) illustrated spores of this fungus from the type material, and the appendages are shown clearly in their figures.

As pointed out by Hoehnel (1919 *a*, 1924), it is obvious that *N. arenaria* is conspecific with *N. schizochlamys* and it is, therefore, regarded here as a synonym of the latter. *N. schizochlamys*, so far as it is known, thus has a host range of two genera in the Cyperaceæ: *Carex* and *Scirpus*.

### Species Not Seen

1. *Neottiospora theæ* Sawada, 1915, *Special Rep. agric. Exp. Sta. Taiwan*, n. **11**: 113, *ic.*; Tanaka, 1919, *Mycologia*, **11**: 153; Saccardo, 1931, *Sylloge Fungorum*, **25**: 185.

We have not seen any material of this species, nor the original description, and the following description is from Tanaka (1919, p. 153): "Spots epiphyllous, irregular, cinereous to brown, sparingly dotted with black, minute fruiting bodies, margin definite, elevated, purplish black; pycnidia subepidermal, black, depressed globose to sphæroid, 84–93 × 108–135 $\mu$, erumpent with ostiola; pycnospores cylindrical, both ends rounded or obtuse, 12–14 × 3 $\mu$, unicellular, hyaline, ciliate at one end; setæ filamentous, 9–11 $\mu$ long. On leaves of *Thea sinensis*, occurring rarely on mature leaves in Formosa and seems to cause no serious damage. Type locality: Shinchikucho Nansho, May 3, 1910. Y. Fujikuro."

It is not unlikely that this may have to be excluded from *Neottiospora* since the conidia are described merely as ciliate at one end. Further, the genus *Neottiospora* appears to be restricted to monocot substrata (Cyperaceæ). Proper assignment of this fungus should await, in any case, study of type material.

2. *Neottiospora philippinensis* Diedicke, 1916, *Ann. mycol.*, **14**: 63; Saccardo, 1931, *Sylloge Fungorum*, **25**: 185.

*Neottiospora philippinensis* was described as follows: "Gehäuse erst von der Epidermis bedeckt, später mit der Mündung hervorbrechend, fast kuglig, dünnwandig, parenchymatisch, dunkelbraun, 150–180 $\mu$ diam., mit ziemlich Weiten (bis 50 $\mu$) etwas unregelmässigen Porus geöffnet. Sporen umgleichseitig spindelforming, unten stumpf, am spitzen oberen Ende mit 2–4 sehr feinen meist rechtwinklig abstehenden Cilien, die verschieden lang sind, oft bis zur Lange der Sporen. Sporen einzellig, hyalin, 11–13 × 2½–3 $\mu$. Auf am Boden liegenden

toten Ästen von *Paramignya longepedunculata*, Los Banos, 10–1–1913, leg. C. F. Baker no. 667" (Diedicke, 1916, p. 63).

We have not seen a specimen and from the description alone it is difficult to state if it is a good *Neottiospora*. However, judging from the host substratum which in this case is Rutaceæ, it is not unlikely that *N. philippinensis* is not in its place !

3. *Neottiospora oryzæ* Hara, 1918, *Diseases of the Rice Plant*, p. 171 (Japanese); Padwick, 1950, *Manual of Rice Diseases*, p. 161.

We have neither seen a specimen nor the original description, and the following description is taken from Padwick (1950, p. 161): "Pycnidia scattered or gregarious, subcuticular, globose, lenticular, furnished with a pore; parenchymatous, dark brown, 100–130 $\mu$ diameter; stylospores long-elliptical, cylindrical or fusiform almost straight, continuous, 17–20 $\times$ 3–4 $\mu$; cilia 3, slender, hyaline, 15–20 $\times$ 0·5–0·7 $\mu$; basidia absent?"

Considering the nature of the substratum, this may indeed be a *Neottiospora*, but here again study of type material is necessary before the fungus can be classified correctly.

4. *Neottiospora laserpitii* Bresadola, 1926, *Studi trentini*, **7**, ser. 2, fasc. 1: 19. (Neither description nor specimen seen.)

## Excluded Species

1. *Neottiospora gigaspora* Fuckel, 1867, *Hedwigia*, **6**: 175.

*Neottiospora gigaspora* was described by Fuckel with Fuckel's "Fungi rhenani 1724". Fuckel's description was as follows: "1724. *Neottiospora gigaspora* Fckl. Peritheciis gregariis, tectis, depressis, atris, ostiolis papillæformibus, erumpentibus; sporidiis oblongo-fusiformibus, multiguttulatis, quadruplo majoribus quam in præcedente, hyalinis. Sporodiorum appendiculos nondum vidi. Ad Caricis ripariæ folia arida."

The exsiccatum bears in addition the locality "Rauenthal" and we have examined this ex Herb. R.B.G. (M.U.B.L. 875). However, no fungus agreeing with Fuckel's description could be seen. In reply to a query, Sir E. J. Salisbury, Director of the R.B.G., Kew, very kindly stated: "Oudemans in Ennumeratio systematica fungorum Vol. 1, p. 1037 prints *N. gigaspora* as a synonym of *Stagonospora macropus* (Berk. & Br.) Sacc." On the basis of this, we are inclined to exclude *Neottiospora gigaspora* from the genus *Neottiospora*.

2. *Neottiospora coprophila* Speg., 1879, *Michelia*, **1**: 481: Saccardo, *Sylloge Fungorum*, **3**: 217.

Spegazzini described the fungus from a collection made in Northern Italy on dung of sheep. It was described as follows: "Peritheciis

minutissimis, 80–70, globosis, astomis (?), irregulariter dehiscentibus, contextu densiusculo, parenchymatico-indistincto; sporulis oblongo-fusoideis, 25×3, utrinque acutiusculis, nubiloso-granuloso-farctis, hyalinis, sessilibus, apice tribus rostellis exilissimis, 20×1, ornatis. Hab. in fimo ovino vetusto in pratis circa Conegliano Italiæ bor., socia *Delitschia Winteri*."

We have studied type material of this fungus and re-described it, giving illustrations of the pycnidiospores (Subramanian and Ramakrishnan, 1956). The fungus produces brownish pycnidia with pseudoparenchymatous walls. The pycnidiospores are hyaline, each with one clear septum dividing it into two unequal cells of which the lower one is almost twice as long as the upper one, subcylindrical, broader towards the apex and narrowed towards the base which is blunt and rounded and 18–21×1·6 $\mu$. Each spore has 3 or 4 filiform, hyaline, divergent, simple appendages arising from all round its flattened apex. The appendages are 14–16 $\mu$ long and are persistent and non-mucoid. This fungus is obviously not a *Neottiospora*, and we have classified it in *Robillarda* Sacc. as *R. coprophila* (Speg.) Subram. & Ramakr. (Subramanian and Ramakrishnan, 1956).

3. *Neottiospora longiseta* Raciborski, 1900, *Parasit. Algen und Pilze Javas*, **3:** 39; Saccardo, 1902, *Sylloge Fungorum*, **16:** 891.

Raciborski described his fungus as follows: "Maculis orbicularibus, rufo-marginatis, centro atris, 1–2 mm. latis, subinde confluentibus et tunc usque 3 mm. latis, phyllachoroideis; peritheciis 1–2 in quaquæ macula, ca. 240 $\mu$ latis, globoso lenticularibus; sporulis ovatis, utrinque acutis, continuis, hyalinis v. pallide griseis, 20–24×10, apice setam pro basi furcatam vel ramos tres divisam tenuissimam hyalinam ca. 30–40 $\mu$ longam gerentibus; basidiis brevissimis, hyalinis. Hab. in foliis Spatholobi littoralis (?) Salak ins Javæ" (from Saccardo, 1902, p. 891). Saccardo (*loc. cit.*) added: "An novi generis typus ? Maculæ phyllachoroideæ atræ minutæ nobis videntur stromata esse; hinc species esset stromatica et ob hunc characterem a *Neottiospora* separanda."

Indeed, Hoehnel (1919 *a*, 1924) indicated that it is not congeneric with *Neottiospora caricina* as re-described by him. We have examined a specimen labelled "*Neottiospora longiseta* Rac. Ma-ti: *Spatholobus littoralis* (?) Java—Salak, leg. M. Raciborski" ex Herb. Tech. Hochsch. Zurich (M.U.B.L. 1267), but we did not see the fungus on it !

It is, however, clear from Raciborski's description, and the more recent one of Hoehnel (1919 *a*, 1924), that the fungus produces pycnidia in dark phyllachoroid stromata and the pycnidiospores are one-celled, acrogenous, spindle-shaped, 20–24×10 $\mu$, each with one apical cilium which has three branches. *N. longiseta* is not congeneric with *N. caricina* as re-described by us in this paper. Hoehnel was right when he established the genus *Ciliochora* to accommodate this fungus and named it *Ciliochora longiseta* (Racib.) Hoehnel (Hoehnel, 1919 *a*, 1924).

4. *Neottiospora lycopodina* Hoehnel, 1909, *Fragm. mykol.*, **7:** 77; Saccardo, 1913, *Sylloge Fungorum*, **22:** 929.

A description of the fungus (from Saccardo, 1913, p. 929) follows: "Pycnidiis in ramulis nigrifactis sparsis, subepidermicis, nigris, coriaceis, globosis, supra late conoideis, ostiolo 10–12 $\mu$ lato, 280 $\mu$ circ. lat. 230 $\mu$ altis, parietibus tenuibus 20–25 $\mu$ cr., minute celluloso-plectenchymaticis; sporulis hyalinis, cylindraceo-clavatis, rectis v. curvulis, apice plerumque rotundatis basi angustato-acutatis 8–12×2–2·5, contextu homogeneo. Hab. in ramulis adhuc vivis Lycopodii complanati, Sonntagsberg prope Waidhofen Austriæ (P. Strasser)."

In 1919 Hoehnel wrote: "*Neottiospora lycopodina* v.H. 1909 hat *Strasseria lycopodina* v.H. zu heizen, mit verkümmerten Stielanhängseln der Konidien" (Hoehnel, 1919 *a*, p. 159). We have not seen a specimen and cannot add anything to Hoehnel's (1919 *a*, 1924) comments on this fungus. However, if Hoehnel's disposition of the fungus is accepted, the name of the fungus should be cited as *Strasseria lycopodina* (Hoehnel) Hoehnel.

5. *Neottiospora yuccæfolia* J. G. Hall, 1915, *Phytopathology*, **5:** 57, ic.; Saccardo, 1931, *Sylloge Fungorum*, **25:** 184–85.

Hall described the fungus as follows: "Pycnidia hemispherical with the mouth upon the flat side, immersed in the tissue of the leaf, 216–324 $\mu$ in diameter. Spores nearly cylindrical, hyaline, with 1–4 cilia at the apex, 38–49·4×7·6–11·4 $\mu$; cilia 30–38 $\mu$ in length. Hab. in follis Yuccæ deperentibus aut mortuis, Pullman, Wash." (Hall, 1915, p. 57).

We have studied type material of this fungus and re-described it as follows: "The fungus forms minute black erumpent pycnidia scattered on both surfaces of leaves. The pycnidia are separate, not immersed in a stroma, spherical and are ostiolate. The pycnidial wall is membranous and made up of two to three layers of pale brown, polygonal cells. The conidia are produced singly on short, stout, hyaline, non-septate, cylindrical, closely packed conidiophores covering the inner surface of the pycnidial wall. The conidia are hyaline, one-celled, nearly cylindrical, straight or slightly curved, with slightly rounded or flat base and with two to six simple, unbranched, filamentous, non-septate appendages arising from several points on or near the rounded apex of the conidium and of about the same length. The conidia are 39·8×8·3 (33–65×4·9–13·3) $\mu$ in size; the appendages are 33–41·5×0·8 $\mu$ in size" (Subramanian and Ramakrishnan, 1954, p. 203).

It is clear that *N. yuccæfolia* is not congeneric with *N. caricina* as re-described by us. Indeed, we have made it the type of a new genus, *Alpakesa* and named it *A. yuccæfolia* (Hall) Subram. & Ramakr. (Subramanian and Ramakrishnan, 1954).

*Sakireeta madreeya* gen. et sp. nov.

It is now necessary to consider the systematic position of Herb. M.U.B.L. 631, on dead culms of *Aristida setacea*, which was recorded as *Neottiospora* sp. by us earlier (Subramanian and Ramakrishnan, 1953).

A detailed description of the fungus follows: The fungus forms immersed or partly immersed pycnidia in the substratum. The pycnidia are distinctly stromatic, single or in groups of more than one, black and of variable shape. In section, the pycnidia are seen embedded singly or in groups in stromatic tissue which is deep brown or brownish black and opaque, of variable thickness and irregular in outline. The actual cavity of each pycnidium is surrounded by a few tiers of brownish or paler coloured thin-walled cells of irregular outline from the innermost layer of which simple, hyaline, short conidiophores are produced. The pycnidiospores are produced singly and acrogenously on the conidiophores; they are hyaline, one-celled, somewhat oblong or more often subcylindrical to clavate and broadest towards the tip, 26 (14–34) $\mu$ long and 5 (4–7) $\mu$ wide. Each spore has an apical appendage. This appendage is mucoid and evanescent, is in the form of an inverted hollow cone with hyaline, thin walls, and 6–17 $\mu$ tall and 5–16 $\mu$ wide. It is similar to the appendages formed in the spores of *Neottiospora caricina* as re-described by us in this paper since it is formed by the rupture of the outer spore wall which later gets everted and takes a funnel-like appearance. However, it cannot be classified in *Neottiospora* since *N. caricina* has simple globose pycnidia with parenchymatous walls, whereas in M.U.B.L. 631 the pycnidia are embedded in dark stromatic tissue. We, therefore, propose to establish a new genus for this fungus. The generic name *Sakireeta* is derived from Sanskrit: सह (*saha*) = with and किरीट (*kireeta*) = tiara, indicative of the tiara-like apical appendage of the spores. The specific epithet, *madreeya*, is also from Sanskrit मद्रीय and refers to Madras, the locality where it was collected.

**Sakireeta** Subramanian and Ramakrishnan gen. nov.

Fungus imperfectus, Sphæropsidales, Sphærioideæ, Hyalosporæ.

Pycnidia formed as locules in a stroma, singly or in groups. Conidiophores simple, hyaline. Pycnidiospores hyaline, one-celled, produced singly and acrogenously, each with an apical appendage. Appendage evanescent, mucoid, in the form of an inverted hollow cone with hyaline, thin walls, formed by the rupture of the outer spore wall which later gets everted and takes a funnel-like appearance.

Pertinet ad Fungos imperfectos, ad Sphæropsidales, Sphæroideas, Hyalosporas.

Pycnidia evoluta ut loculi in stromatibus, singula vel aggregata. Conidiophori simplices, hyalini. Pycnidiosporæ hyalinæ, unicellulatæ, productæ singulariter et acrogene, singulæ appendice apicali ornatæ.

Appendix evanescens, mucoidea, coni inversi vacuique instar parietibus tenuibus et hyalinis, efformata per disruptionem muri exterioris sporarum, qui postea evertitur et evadit infundibuliformis.

Species typica sequens.

**Sakireeta madreeya** Subramanian and Ramakrishnan sp. nov.

Stromata pycnidialia dispersa, nigra, immersa in substratum. Pycnidia efformata ut loculi in stromate, singula vel aggregata, magnitudinis et formæ variabilis. Series stromatica variabiliter crassa, fusca et opaca, ambitu irregulari. Cortex stromaticus vestitus intus nonnullis seriebus cellularum polygonalium, pallidium vel fuscarum, parietibus tenuibus præditarum. Conidiophori surgentes ex intima serie cellularum, simplices, hyalini, breves, non-septati, producentes pycnidiosporas singulariter et acrogene. Pycnidiosporæ hyalinæ, unicellulatæ, aliquantum oblongæ vel sæpius subcylindricæ, vel distincte, clavatæ, 26 (14–34) $\mu$ longæ, 5 (4–7) $\mu$ latæ, singulæ appendice apicali ornatæ. Appendix mucoidea, evanescens, coni inversi vacuique instar, parietibus tenuibus, hyalinis prædíti, 6–17 $\mu$ alta, 5–16 $\mu$ lata.

Typus lectus in culmis emortuis *Aristidæ setaceæ* Retz. in loco Choolai, in Madras, die 27 mensis septembris anni 1951 a K. R. et postius in Herb. M.U.B.L. sub-numero 631.


## Summary

This paper is a contribution to the taxonomy of the genus *Neottiospora* Desm.

A study of type material of the type species, *N. caricina* (Desm.) Hoehnel showed that it belongs to the Fungi imperfecti—Sphæropsidales—Sphærioideæ—Hyalosporæ and that the pycnidiospores have characteristic appendages. Desmazières described the spores as many-ciliate at the apex and this has been followed by many workers; Hoehnel, who re-studied the fungus, stated that the spores had no apical appendages but only a persistent, tattered conidiophore each at the base. Both these views are considered incorrect by the authors. Spores of *N. caricina* each have only one apical appendage; this appendage is mucoid, evanescent, in the form of an inverted hollow cone with hyaline, thin walls, and is formed by the rupture of the outer spore wall which later gets everted. The generic description of *Neottiospora* is accordingly emended.

Besides the type species, two others are included in the genus, after study of type material: *N. paludosa* Sacc. & Fiori and *N. schizochlamys* Ferd. & Winge. *N. arenaria* Sydow is accepted as a synonym of *N. schizochlamys*.

The genus *Tiarosporella*, which was established by Hoehnel to accommodate *Neottiospora paludosa*, *N. schizochlamys* and *N. arenaria*, is reduced to synonymy with *Neottiospora* Desm. as emended in this paper.

One collection of a pycnidial fungus reported from Britain by Berkeley and Broome as a variety of *N. caricum* with dark-coloured spores has been re-studied. The spores of this fungus have each an apical appendage similar to that of spores of *N. caricina*, but since it has phæospores it is removed from the hyalospored genus, *Neottiospora*; it is made the type of a new genus *Samukuta* and named *S. berkeleyii*.

Material of several species classified in *Neottiospora* has not been available and these are briefly discussed on the basis of available descriptions. Some species are definitely excluded from the genus as re-described here, on the basis of the observations of the authors or those of other investigators. These are: (1) *Neottiospora gigaspora* Fuck. = *Stagonospora macropus* (Berk. & Br.) Sacc., fide Oudemans; (2) *Neottiospora coprophila* Speg. ≡ *Robillarda coprophila* (Speg.) Subram. & Ramakr.; (3) *Neottiospora longiseta* Racib. ≡ *Ciliochora longiseta* (Racib.) Hoehnel; (4) *Neottiospora lycopodina* Hoehnel ≡ *Strasseria lycopodina* (Hoehnel) Hoehnel; and (5) *Neottiospora yuccæfolia* Hall ≡ *Alpakesa yuccæfolia* (Hall) Subram. & Ramakr.

The three species definitely assigned to the genus *Neottiospora* in this paper (*viz.*, *N. caricina*, *N. paludosa* and *N. schizochlamys*) appear to be confined to the Cyperaceæ.

One collection of a pycnidial fungus on *Aristida setacea* from Madras, previously assigned to *Neottiospora*, is made the type of a new genus, *Sakireeta* and named *S. madreeya*. This fungus has hyalospores with apical appendages very similar to those of *Neottiospora* spp., but differs from them in producing stromatic pycnidia singly or in groups.

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# ON A FORM OF *RAPHIDIOPSIS MEDITERRANEA* SKUJA

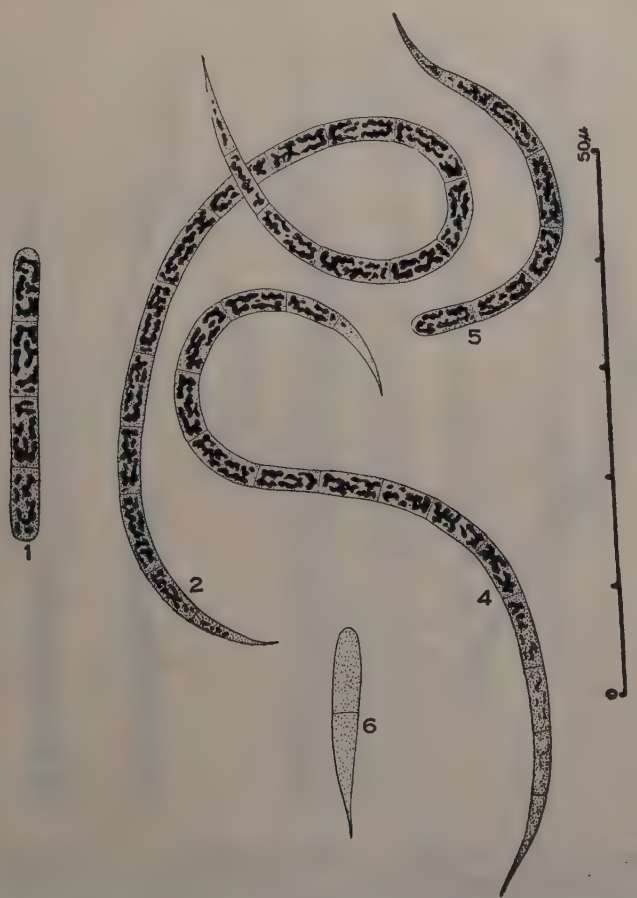
By K. V. N. Rao

*Hydrobiological Research Laboratory, Department of Botany*

*Osmania University, Hyderabad-Deccan-7*

(Received for publication on October 8, 1956)

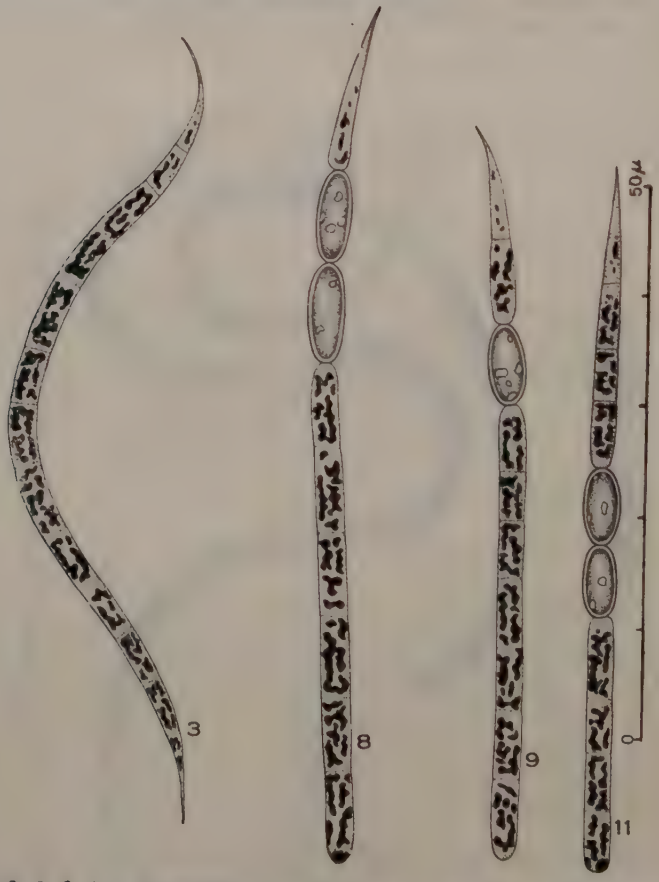
The genus *Raphidiopsis* was established by Fritsch and Rich (1929) on the type species, *R. curvata*, collected from freshwater pans in West Africa. This species was later reported from Brazil by Drouet (1938),




Figs. 1, 2 and 4 to 6. *Raphidiopsis mediterranea* Skuja. 1. Trichome with both the ends rounded. 2 and 4 to 5. Trichomes curved and semicircular. 6. Two-celled trichome without pseudovacuoles.

from Ohio by Daily (1945), from Florida by Brannon (1952) and from Ceylon by Holsinger (1955). Skuja (1937) described a second species, *R. mediterranea*, from Lake Kastoria near Macedonia, in Greece. Fremy (1938) reported this species from Normandy. A third species, *R. indica*, was described by Singh (1942) from certain ponds at Banaras. Unidentified forms of *Raphidiopsis* have also been reported from Rangoon (Skuja, 1949) and from Ceylon (Holsinger, 1955).

A form of *Raphidiopsis* was collected by the writer from a fresh-water pond near the Fisheries Department, Hyderabad, in July 1953, and the same alga was subsequently found in similar habitats around the twin cities of Hyderabad and Secunderabad.

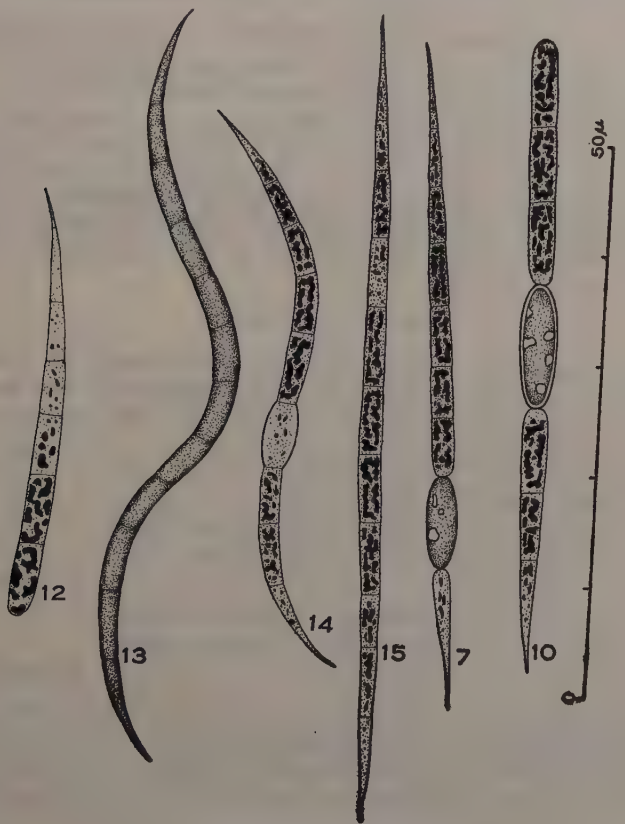



FIGS. 3, 8, 9, 11. *Raphidiopsis mediterranea* Skuja. 3. Trichome Sigmoid. 8. Trichome with paired sub-terminal akinetes. 9 and 11. Trichomes with a single and paired intercalary akinetes.

The alga made its appearance during the second week of July and steadily increased in number during the subsequent months, reaching

its maximum in December–January. A sharp fall in their number was, however, noted in the early summer of 1954. In the second year of observation (1954–55), it made its appearance rather late, *i.e.*, the first week of August 1954, but attained its maximum during the same period as in the previous year (*i.e.*, December–January).

*Description of the alga.*—The alga consists of free-floating trichomes mostly straight, often curved or weakly sigmoid (Figs. 15, 2–5). The trichomes generally consist of 6–12 cells each, but trichomes having smaller or larger number of cells are by no means rare (Figs. 6 and 2). They are attenuated at both the ends. They frequently fragment into two pieces, with the result that one of their ends has a cell with a rounded end. Fragments, when they break off from the middle of trichomes, may be rounded at both the ends.




FIGS. 7, 10, 12–15. *Raphidiopsis mediterranea* Skuja. 7. Trichome with a single intercalary akinete. 10. Trichome with a single sub-terminal akinete. 12. Trichome with one end rounded and pseudovacuoles gradually disappearing. 13. Curved trichome without pseudovacuoles. 14. Trichome with an immature akinete. 15. Straight trichome with both the ends tapering.

The attenuated ends of trichomes may consist of one, two or, in rare cases, more than two cells, but the terminal cell is always attenuated to a sharp tip. The length of the trichome is variable and ranges between 40–110 $\mu$, rarely reaching 180 $\mu$.

The cells are 1·9–3 $\mu$ broad, and 2–5 times as long as broad. The trichome is not constricted at the cross-walls. The cells are bluish-green in colour, and normally possess dark brown, pseudovacuoles with irregular contours. But sometimes one or more cells or even an entire trichome may have no pseudovacuoles (Figs. 4, 6, 12 and 13). In such cases, the cells appear as uniformly blue-green, but on closer examination under higher magnifications, some of the cells reveal signs of their having had pseudovacuoles, which have subsequently disappeared gradually (Figs. 4 and 12). These cells or trichomes give the impression of their being in an unhealthy condition.

Akinetes were found in a few individuals in various stages of development. The akinetes when fully mature are ellipsoid with rounded ends and their walls are brown, thick and smooth (Figs. 8–11). But when they are younger, they are thin-walled and barrel-shaped with truncated ends (Fig. 14). They are 2·8–3·4 $\mu$ broad and 6·7–9·3 $\mu$ long or rarely up to 13·5 $\mu$ long. They occur either singly (Figs. 7, 9 and 10), or in pairs (Figs. 8 and 9) and are subterminal (Fig. 7) or intercalary (Figs. 9-11 and 14) in position. The contents of the spores are blue-green in colour and contain a few large highly refractive granules scattered in them.

## Systematic Position

So far three species of *Raphidiopsis* are known. An analysis of the description in the available literature suggests to the writer the following key as the basis for the separation of the species:—

| | |
|---|---|
| Trichomes often curved or spirally coiled .. | *R. curvata* |
| Trichomes generally straight | |
| Trichomes constricted at the cross-walls, cells 6–8 times as long as broad, spores 3·3–4 × 7·8–9·2 $\mu$ .. .. .. | *R. indica* |
| Trichomes unconstricted at cross-walls, cells up to 2–4 times as long as broad, spores 2·5–3·5 × 6·5–13·5 $\mu$ .. .. .. | *R. mediterranea* |

The present alga, in having the trichomes which are mostly straight, and not constricted at the cross-walls, appears to be *R. mediterranea*. The alga agrees with *R. mediterranea* in the dimensions of the trichome and the spores also. This species has so far not been recorded from India.

## Acknowledgement

The author thanks Dr. M. R. Suxena, for suggestion of this work, and his constant help during the preparation of this paper. He is greatly indebted to Prof. M. O. P. Iyengar for his helpful suggestions and

valuable criticism. He is thankful to Prof. M. Sayeeduddin for his encouragement, and to the Government of India for the award of a scholarship, during the tenure of which this paper was prepared.

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# THE CLAVARIACEÆ OF THE MUSSOORIE HILLS—VI

By K. S. Thind and Sukh Dev

*Botany Department, Panjab University, Amritsar*

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This paper is intended to record more Clavarias from the Mussoorie Hills (5,000–7,500 feet altitude in the North-Western Himalayas) as a part of the study of the Fungal Flora of that region undertaken by the senior author and his students (Thind and Anand, 1956 *a*; Corner, Thind and Anand, 1956; Thind and Anand, 1956 *b*; Thind and Anand, 1956 *c*; Thind and Dev, 1956). Of the eight Clavarias described here four belong to Ramaria-series, three to Clavariadelphus-series, and one to Clavaria-series. All of these are new records for India.

The classification of Corner, 1950, has been followed in this series.

The number of the Clavarias are the serial numbers of the Flora.

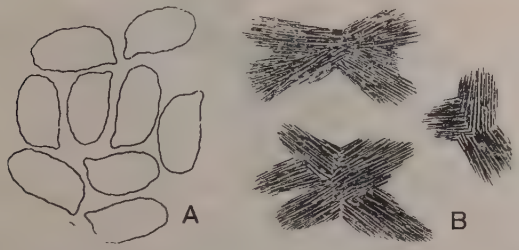
Type collections have been deposited in the Herbarium of the Panjab University. Duplicate material is at the Botany School, University of Cambridge, England.

*Ramaria-series*

36. *Ramaria flavo-brunnescens* (Atk.) Corner
"Bright orange form"

*Fructifications* 20 cm. tall, 16 cm. wide, solitary, erect, large-sized, massive, radial, trunk absent but with a white massive embedded base, profusely branched, fleshy, smooth, glabrous, bright orange: branching polychotomous below, dichotomous above, irregular, unequal, elongate: primary branches thick, elongate, slightly rugulose, up to 2 cm. wide: ultimate branchlets mostly in parallel pairs, small to very long, up to 1·5 cm. long: apices concolorous, blunt, fertile: flesh white, unchanging: smell and taste inparticular.

*Hymenium* spread all over, thickening, with numerous embedded spores and basidia, up to 120 $\mu$ thick. *Basidia* 50–70 $\times$ 6·8–10 $\mu$, clavato-elongate: sterigmata 4, stout, straight, 2·6–8·5 $\mu$ long. *Basidiospores* 8·8–10·8 $\times$ 4–5·2 $\mu$, pale brown to ochraceous, wall dark, mostly ellipsoid to ellipsoid-cylindrical, sometimes broadly ellipsoid, papillate, papilla up to 0·8 $\mu$ long, distinctly verruculose, aguttate. *Hyphæ* monomitic, 3·4–12·7 $\mu$ wide, hyphal cells up to 162 $\mu$ (or more) long, hyaline, thin-walled, branched, inflated, septate, septa at short to long intervals, clamped, clamps very sparsely present, with numerous needle-like crystals arranged in stellate masses in the context (Plate IV, Fig. 1, Text-Fig. 1, A–B).




TEXT-FIG. 1. *Ramaria flavobrunnescens* (Atk.) Corner. A. Verruculose basidiospores, ×1150. B. Needle-like crystals arranged in stellate masses, ×500.

Collected on soil amid mosses under Oak forest, The Park, Mussoorie, September 8, 1954, 68.

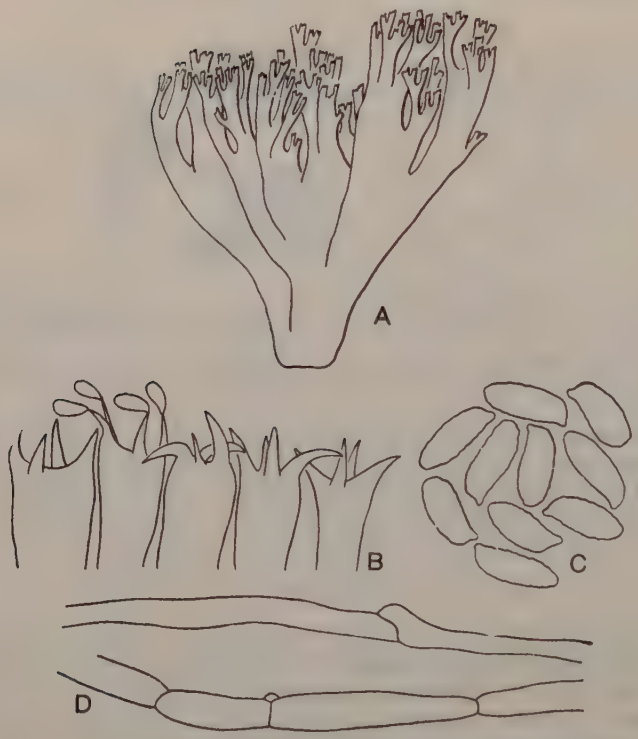
This collection (n. 68) apparently belongs to *Ramaria flavobrunnescens* (Atk.) Corner but possesses crystalloid bodies in the context. It differs from the Mussoorie collection n. 61 of *Ramaria flavobrunnescens* (Atk.) Corner (Thind and Dev, 1956) in the possession of bright orange fruit bodies and the crystalloid bodies in the context.

37. *Ramaria flavobrunnescens* (Atk.) Corner var. *aurea* Coker

*Fructifications* 5·5–9·5×3–8 cm., gregarious, erect, massive and medium-sized, radial, trunk present or absent, profusely branched, fleshy, brittle, smooth, glabrous, orange with yellow tips, on drying turning reddish brown and flattened into a thin sheet (as if it were turgid or gelatinous when fresh): trunk, when present, up to 4·3×2 cm., white, massive, narrowed down at the base, radial: branching polychotomous below, dichotomous above, unequal and irregular, crowded: primary branches up to 1·1 cm. wide, short to elongate: ultimate branchlets very short to 1·5 mm. long, in pairs or crowded due to close dichotomy: apices yellow, blunt or obtuse: flesh white, unchanging: smell and taste inparticular. *Hymenium* spread all over except the white basal parts, not thickening, up to 54 μ thick. *Basidia* 6–9 μ wide, clavate: sterigmata 4, straight or reflexed, 2–7·6 μ long. *Basidiospores* 8·8–10·4×3·2–4 μ, pale brown, wall dark, ellipsoid-elongate, papillate, papilla up to 0·6 μ long, finally verruculose-rough, aguttate, not striated. *Hyphæ* monomitic, 3·8–10 μ wide, hyaline, thin-walled, branched, inflated, septate, septa usually at short intervals, clamped (Text-Fig. 2, A-D).

Collected on soil under Oak forest, Dick Road, Mussoorie, August 20, 1955, 69.

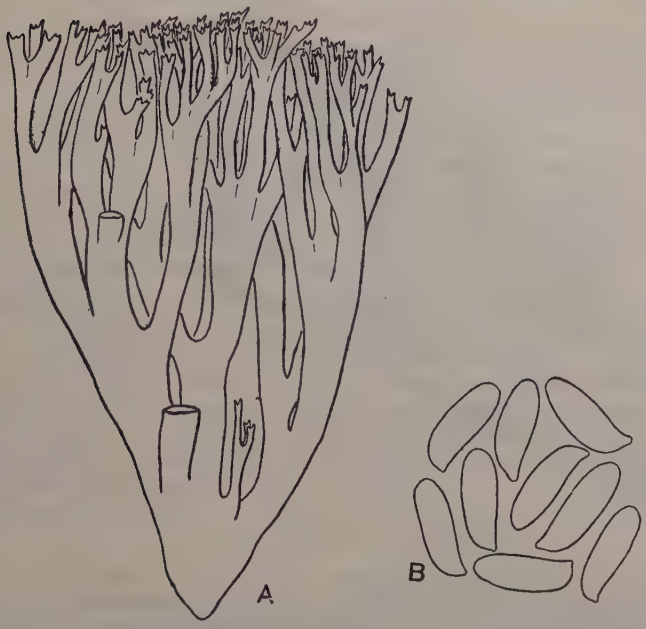
This collection closely resembles *Ramaria flavobrunnescens* (Atk.) Corner var. *aurea* Coker and is marked by smaller size, orange colour with yellow tips, unchanging flesh, and elongate-ellipsoid spores (8·8–10·4×3·2–4 μ). It differs from the bright orange form of *R. flavobrunnescens* (n. 68) in the smaller size and yellow tips of its fruit bodies, and in the absence of crystalloid bodies in its context.




TEXT-FIG. 2. *Ramaria flavobrunnescens* var. *aurea* Coker. A. Fructification, $\times\frac{1}{2}$. B. Basidia with straight and reflexed sterigmata, $\times 1150$. C. Ellipsoid elongate, finely verruculose-rough basidiospores, $\times 1150$. D. Inflated, clamped hyphæ, $\times 500$.

### 38. *Ramaria obtusissima* (Pk.) Corner

*Fructifications* up to $19 \times 12$ cm., scattered, erect, large-sized, massive, radial, trunk absent, profusely branched, fleshy, smooth, glabrous, pallid or tan white, on drying turning reddish brown: base massive, stubby, short, up to 3 cm. wide, giving rise to stout main branches at the ground level: branching polychotomous below, dichotomous above, branches elongate, slightly rugulose, dense: primary branches stout, up to 1·4 cm. wide: ultimate branchlets bifid or crowded, very minute to 4 mm. long: apices blunt: flesh white, unchanging: smell and taste inparticular. *Hymenium* spread all over, slightly thickening, up to 94 $\mu$ thick. *Basidia* 5–9·6 $\mu$ wide, clavate: sterigmata 4, straight to slightly incurved, 2–5·6 $\mu$ long. *Basidiospores* $10{\cdot}4–12 \times 3{\cdot}2–4{\cdot}8\ \mu$, pale brown, wall dark, ellipsoid-elongate or narrowly ellipsoid-cylindric, papillate, papilla up to 0·6 $\mu$ long, smooth, not striated, aguttate. *Hyphæ* monomitic, 4–16 $\mu$ wide, hyphal cells up to 282 $\mu$ (or more) long, hyaline, thin-walled, branched, inflated, septate, septa at long intervals, sometimes constricted at the septa, clamped, clamps rare (Text-Fig. 3, A–B).




TEXT-FIG. 3. *Ramaria obtusissima* (Pk.) Corner. A. Fructification with minute, blunt apices, $\times\frac{1}{2}$. B. Ellipsoid-elongate, smooth-walled basidiospores, $\times 1150$.

Collected on soil, Chakrata Toll, Mussoorie, August 13, 1956, 70.

This collection clearly belongs to *Ramaria obtusissima* (Pk.) Corner. It resembles the 'rough spored form' of the same species collected and described from the Mussoorie Hills (Thind and Anand, 1956) in all respects except that its spores are smooth-walled.

### 39. *Lentaria mucida* (Fr.) Corner

*Fructifications* 2·5–10 mm. tall, gregarious, erect, small-sized, radial, trunk present, simple, clavate, fleshy, smooth, glabrous: head 1·5–5 × 0·5–1 mm., white, mostly bent or allantoid, sometimes straight, apex sterile, mostly acute, sometimes obtuse: trunk 1–5 × 0·3–0·5 mm., light green (due to algal growth), straight, cylindrical, solid, short, glabrous, smooth, somewhat broader at the base, algæ associated with the base: smell and taste inparticular. *Hymenium* spread all over, the head except the apex, also absent on the trunk, not thickening, up to 28 $\mu$ broad. *Basidia* up to 25 × 5 $\mu$, clavate: sterigmata 6, sometimes 4–5, straight, up to 5 $\mu$ long. *Basidiospores* 4·4–5·6 × 2–2·4 $\mu$, hyaline, ellipsoid, smooth, aguttate. *Hyphæ* monomitic, 2·4–5 $\mu$ wide, hyphal cells up to 304 $\mu$ long or even more, hyaline, thin-walled, branched, slender, narrow, uninflated, septate, septa at long intervals, clamped, H-pieces also observed (Text-Fig. 4, A–D).

Collected on decaying logs of *Picea morinda* Link under Picea forest, Kadu Khal, Mussoorie, September 6, 1955, 71.


TEXT-FIG. 4. *Lentaria mucida* (Fr.) Corner. A. Simple, stipitate fructifications, ×5. B. Basidia with 4–6 sterigmata and attached spores, ×1150. C. Small, ellipsoid, smooth-walled basidiospores, ×1150. D. Narrow, clamped hyphæ, ×500.

The presence of 4–6 sterigmata in this collection (n. 71) of the Mussoorie Hills is an intermediate character between *Lentaria mucida* (Fr.) Corner and *L. coronilla* (Martin) Corner and shows that these two species are not distinct. Besides, both are phycophilous.

Unlike *L. mucida*, the apices of the fruit bodies of n. 71 are sterile. It is not known whether apices of *L. coronilla* are fertile or sterile.

### *Clavariadelphus-series*

### 40. *Clavariadelphus junceus* (Fr.) Corner

*Fructifications* 1·5–9 cm. tall, gregarious, scattered, erect, slender, radial, trunk present, simple, fleshy-tough, also brittle, smooth, glabrous: head long, 0·5–7·5 cm.×0·7–0·8 mm., milk white, filiform, cylindrical, straight, narowed towards the top, apex fertile, obtuse: trunk short, 1–1·5 cm.×0·4–0·7 mm., brownish red, appearing smooth, outer hyphæ agglutinated and brownish red: flesh white both in the

head and the trunk: smell and taste inparticular. *Hymenium* spread all over except the trunk, not thickening, up to 30 $\mu$ broad. *Basidia* 20–24 × 5–7 $\mu$, hyaline, clavate: sterigmata 4, rarely 2, straight, 3–8 $\mu$ long. *Basidiospores* 5·2–7·2 × 3·2–4 $\mu$, hyaline, broadly ellipsoid, papillate, papilla up to 0·8 $\mu$ long, smooth, aguttate. *Caulocystidia* minute, scarcely projecting beyond the stem surface, mostly in groups. *Hyphæ* monomitic, 7–20 $\mu$ wide, narrow ones 2–4 $\mu$ wide, hyphal cells up to 340 $\mu$ long, hyaline, thin-walled, branched, inflated, a few narrow and uninflated, septate, septa at short to long intervals, narrow hyphæ clamped, inflated ones not clamped (Text-Fig. 5, A–C).

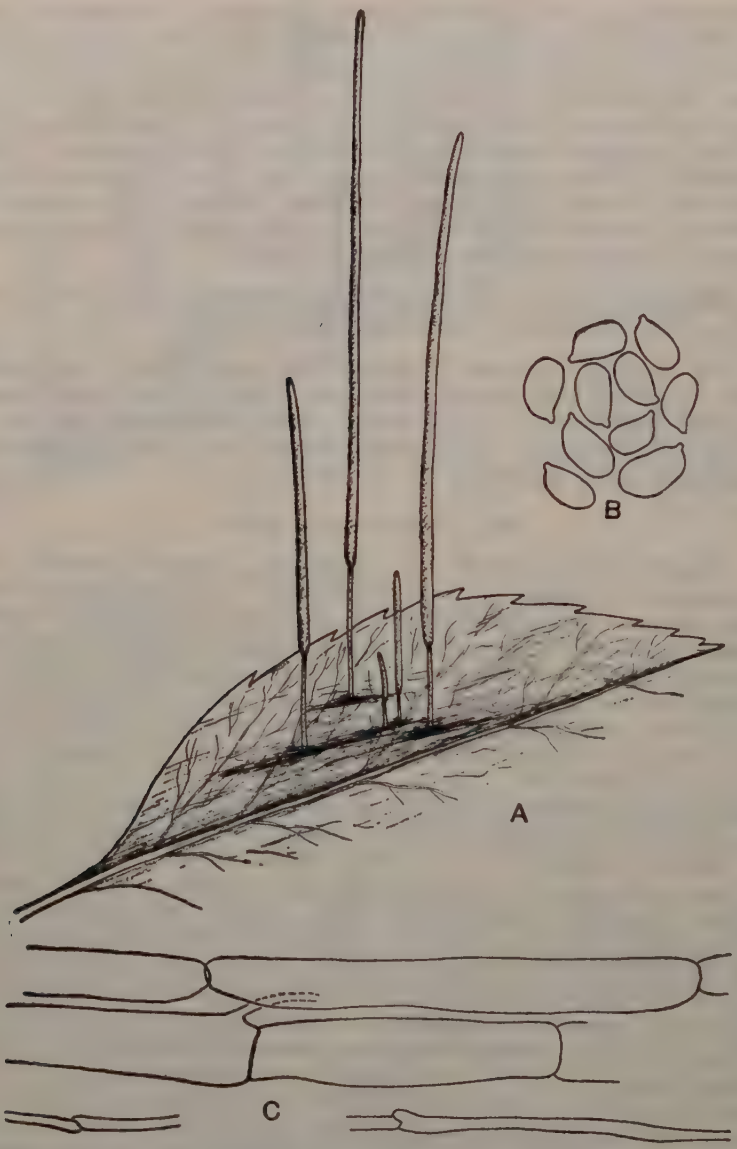
Collected on dead leaves and decaying fruits of *Quercus incana* Roxb., The Park Road, Mussoorie, August 5, 1955, 72.

The present collection is marked by long filiform fructifications with white long head and brownish red, distinct, short trunk, broadly ellipsoid spores (5·2–7·2 × 3·2–4·4 $\mu$), and clamps being present only on the narrow hyphæ. Its caulocystidia are short and much less developed than those described for the species.

41. *Typhula ovata* Karst.

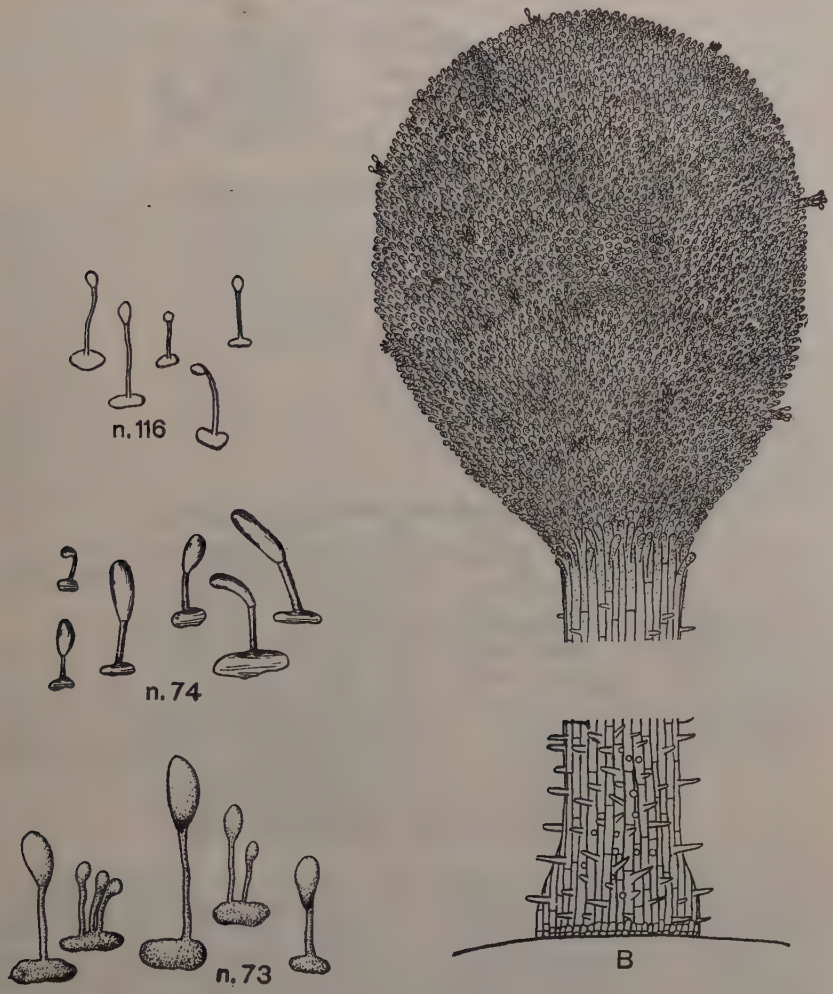
*Fructifications* 1–6 mm. tall, gregarious, scattered, mostly 1 per sclerotium, sometimes 2–3 per sclerotium, erect, small-sized, radial, trunk present, simple, fleshy, smooth, glabrous: head 0·26–2·5 × 0·22–1 mm., mostly white, sometimes yellow, enlarged, globose when young, becoming ovoid (sometimes short-cylindric) at maturity, straight, apex rounded, fertile: trunk 0·6–4 mm. × 75–300 $\mu$, white, sometimes brownish at the base, straight, of uniform diameter, sometimes slightly enlarged at the base, solid, appearing smooth: flesh white, unchanging: smell and taste inparticular. *Hymenium* spread all over the head, trunk sterile, not thickening, up to 32 $\mu$ thick: subhymenium present. *Basidia* 16–26 × 4–7 $\mu$, hyaline, clavate: sterigmata 4, sometimes 2, straight or slightly incurved, 3–7 $\mu$ long. *Basidiospores* 7–10·8 × 3–4·8 $\mu$, hyaline, ellipsoid, or ellipsoid-allantoid, papillate, papilla minute, smooth, aguttate. *Caulocystidia* small, longer and more abundant at the base of the stem, hyaline, narrow with blunt ends, thick-walled, wall up to 1 $\mu$ thick, straight, aseptate, 5–30 × 4–8 $\mu$. *Hyphæ* monomitic, 4–8 $\mu$ wide, hyphal cells up to 206 $\mu$ long or even more, hyaline, thin-walled, branched, uninflated, or somewhat inflated, septate, septa at long intervals, clamped, H-pieces observed occasionally: context hyphæ compact, parallel, longitudinal: subhymenial hyphæ loose and obliquely placed. *Sclerotium* 0·26–2·5 × 0·2–0·5 mm., spherical when young, later on becoming compressed or lenticular, brown, smooth: in surface view with irregular cells, the lumina 5–54 × 4–12 $\mu$, separated by wavy brown walls, wall slightly thickened, thickening up to 1·6 $\mu$: medulla white, wholly agglutinated, indistinguishable from the cortex (*i.e.*, cortex absent): cuticle absent: epidermis agglutinated (Text-Fig. 6, A–F).

Collected on decaying leaves of *Cautlea lutea* Royle, Dhobi Khad, Mussoorie, August 10, 1955, 73. On dead leaves of *Pteris cratica* L.



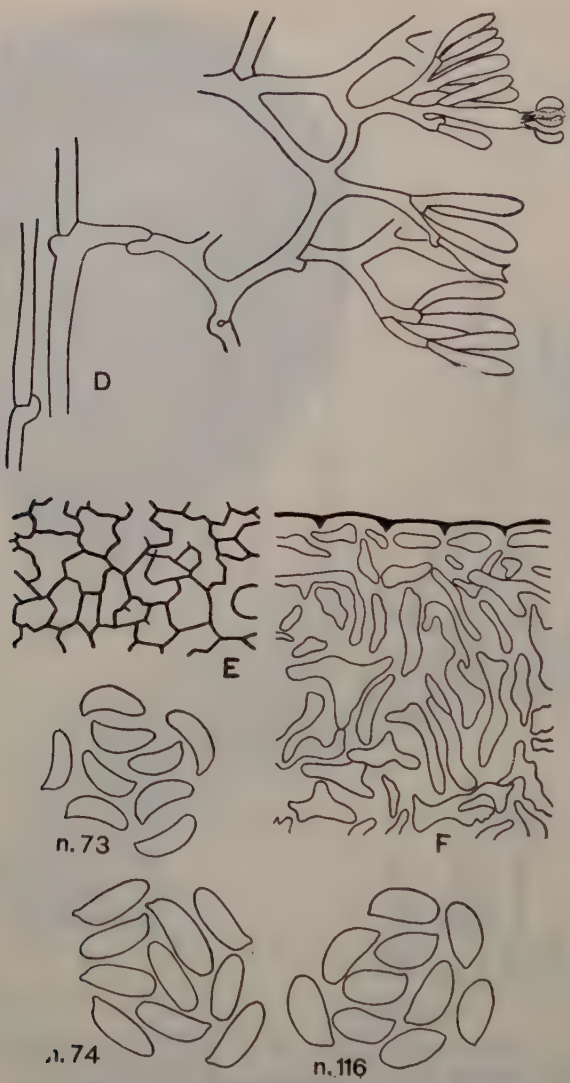

TEXT-FIG. 5. *Clavariadelphus junceus* (Fr.) Corner. A. Slender, simple, stipitate, fructifications, ×5. B. Broadly ellipsoid, smooth-walled basidiospores, ×1150. C. Narrow hyphæ clamped and inflated hyphæ without clamps, ×500.

under *Cedrus deodara* forest, Dhanolti, Mussoorie, August 27, 1955, 74. On dead leaves of a grass, Jabber Khet Toll, Mussoorie, August 14, 1955, 116.




TEXT-FIG. 6. *Typhula ovata* Karst. A. Fructifications of n. 73, n. 74 and n. 116 all arising from the sclerotium, ×5. B. Magnified fructification of n. 116, ×150. (Note the thick-walled caulocystidia with blunt ends.)

This species was abundantly collected from several localities of Mussoorie hills. Fruit bodies are always white except n. 116 in which the heads were yellow and they are taller in 73 than in n. 74 and n. 116. The heads of the fruit bodies of n. 116 are much narrower than the other two collections. The basidia of n. 74 are narrow and always 2-spored. The basidiospores of n. 74 are narrower and bigger (8–10·8×3·2–4 $\mu$); those of n. 116 are ellipsoid (7·2–8·1×3·6–4·8 $\mu$); while those of n. 73 are ellipsoid-allantoid (6·4–8×2·6—3·2 $\mu$).




TEXT-FIG. 6 (*Continued*). *Typhula ovata* Karst. C. Basidiospores of n. 73, n. 74, and n. 116, ×1150. D. Part of a hypha from the head of n. 73, ×500. E. Surface view of sclerotium of n. 73, ×500. F. Part of transverse section of sclerotium of n. 73, ×500.

The present collections are also allied to *Typhula viburni* Remsberg but the latter differs in the ovoid spores and brown colour of the fruit bodies, and in the outer investing hyphæ of the sclerotium. The present three collections are also allied to *T. elegans* (B. *et* C.) Corner which, however, has much larger spores.

Corner (personal correspondence, 1956) has recently got some collections of *T. ovata* from Holland. His collections differ from the Mussoorie collections in having ventricose, thin-walled caulocystidia with tapering filiform apex. The caulocystidia of the Mussoorie collections of this species are thick-walled with blunt apex.

### 42. *Pistillaria granulata* Pat.

*Fructifications* up to 2 mm. tall, gregarious, scattered, erect, small-sized, radial, trunk present, simple, clavate, fleshy, smooth, glabrous: head up to $1{\cdot}5\times0{\cdot}3$ mm. light pink to deep pink, cylindrical, bent or allantoid, apex rounded, fertile: trunk up to $412\times145\,\mu$, white, straight, cylindrical: smell and taste inparticular. *Hymenium* spread all over except the trunk, not thickening, up to $30\,\mu$ broad. *Basidia* $24–28\times4–5{\cdot}6\,\mu$ clavate light pink: sterigmata mostly 2–3, sometimes 4, stout, straight, $4–6\,\mu$ long. *Basidiospores* $5{\cdot}6–6{\cdot}4\times2{\cdot}4–3{\cdot}2\,\mu$, light pink, narrowly ellipsoid or ellipsoid-elongate, smooth aguttate. *Hyphæ* monomitic, $2–8\,\mu$ wide, hyaline, thin-walled, branched, septate, septa at long intervals, slightly swollen on one side of the septa, sometimes gliding over each other at the septa and gliding over portion resembling a clamp, parallel, longitudinal (Text-Fig. 7, A–C).

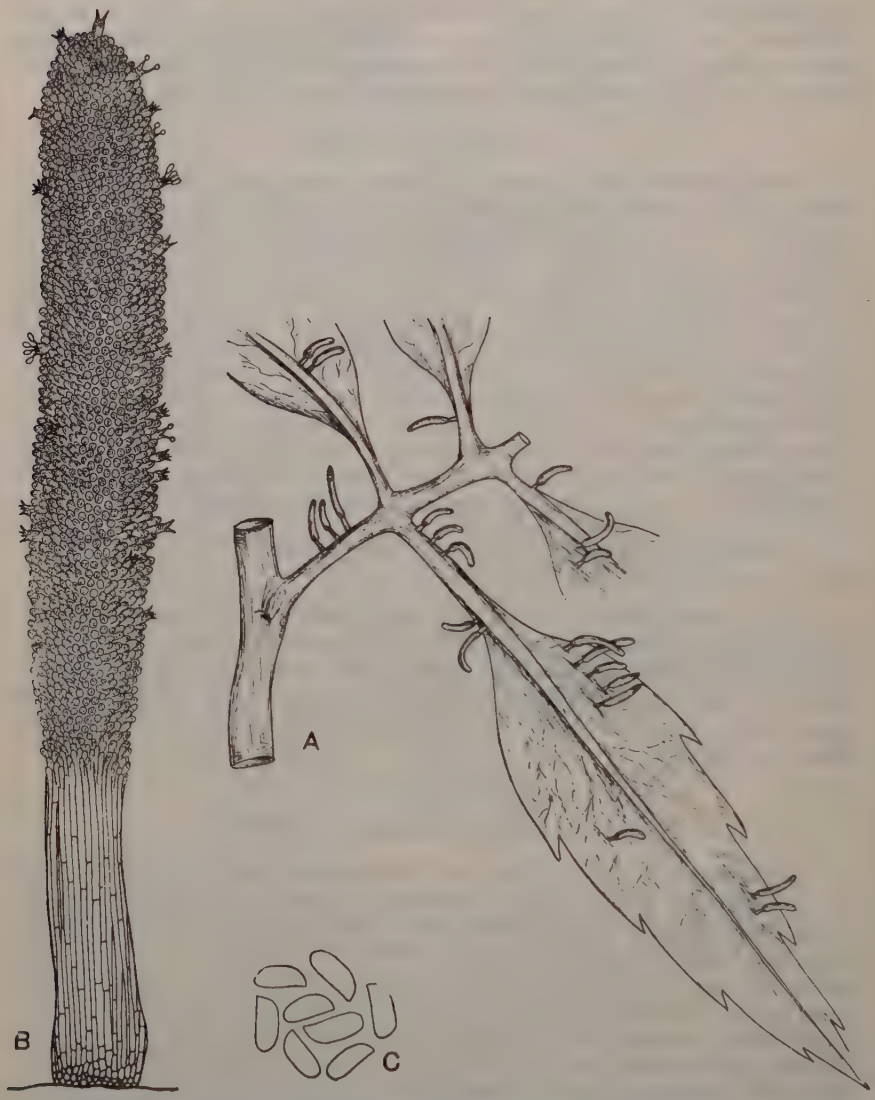
Collected on dead leaves of a composite, The Municipal Gardens, Mussoorie, August 18, 1955, 117.

This collection (n. 117) is indistinguishable from the meagre description of *Pistillaria granulata* Pat. It is characterized by small, simple clavate, and pink coloured fruit bodies, 2–4 sterigmata, and light pink, smooth, small and narrowly ellipsoid spores. This collection also comes near *P. rhodocionides* Corner but it has much smaller spores than the latter.

### *Clavaria-Series*

### 43. *Ramariopsis Kunzei* (Fr.) Donk

*Fructifications* $2{\cdot}5–6{\cdot}5$ cm. tall gregarious usually cæspitose with 2–8 fruit bodies in a cluster, cæspitose clusters up to $4{\cdot}5$ cm. broad, sometimes solitary, erect, small-sized, radial, trunk present, profusely branched, fleshy, brittle, smooth, delicately hairy on the trunk and bases of lower branches, white, sometimes white with a light orange tints on the branches: trunk white, $0{\cdot}6–3\times0{\cdot}1–0{\cdot}3$ cm., radial, delicately hairy: hairs hyaline, hypha-like, simple, rarely branched, septate, slightly thick-walled, narrow, up to $225\times3\,\mu$, clamped, sometimes not clamped: branches radial, dichotomous, 3–5 times branched, unequal, in alternating planes, sometimes fused together: primary branches up to 2 mm. wide: ultimate branchlets very minute to long, up to 7 mm. long, rarely up to $2{\cdot}5$ cm. long when a branch does not show any terminal bifurcation: apices acute to subacute, sterile, hairy (probably due to divergent hyphæ or the lax beginnings of the hymenium): flesh white, fibrous: taste bitter: smell inparticular. *Hymenium* spread all over except the sterile apices and the sterile trunk, thickening, up to $120\,\mu$ thick. *Basidia* $25–32\times4{\cdot}5–8\,\mu$. clavate: sterigmata 2–4,




TEXT-FIG. 7. *Tristiolaria granulata* Pat. A. Small, simple, stipitate, fructifications, ×5. B. Magnified fructification, ×150. C. Ellipsoid, smooth-walled basidiospores, ×1150.

stright, up to 6·5 μ long. *Basidiospores* 4·5–5·5×2·6–4 μ, hyaline to subhyaline, globose to subglobose, or obovate due to papilla, papilla up to 0·8 μ long, echinulate, spines prominent, sparse, up to 0·4 μ long and sharp-pointed, uniguttate, gutta filling two-third to three-fourth of the spore cavity. *Hyphæ* monomitic, 2–14 μ wide, hyphal

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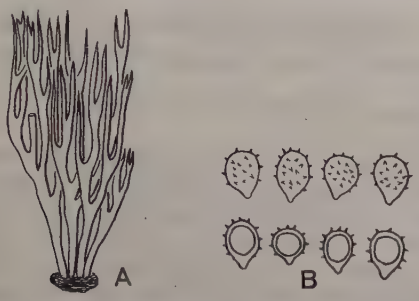
cells up to 220 $\mu$ long or even more, inflated, narrow ones uninflated, interwoven, hyaline, thin-walled, branched, branches sometimes small and antler-like, septate, septa at short intervals, at longer intervals in narrow hyphæ, clamped, sometimes not clamped, entire to wavy and giving a beaded appearance (Text-Fig. 8, A–B).




TEXT-FIG. 8. *Ramariopsis Kunzei* (Fr.) Donk. A. A cæspitose cluster of fructifications, × 1. B, Globose to obovate echinulate basidiospores with one large gutta, × 1150.

Collected on humicolous soil under Oak forest, The Park, Mussoorie, September 8, 1954, 118. On soil under Oak forest, Dhobi Khud, Mussoorie, September 3, 1954, 119.

These two collections (n. 118 and n. 119) undoubtedly belong to *Ramariopsis Kunzei* (Fr.) Donk. The basidia of n. 118 are mostly 2-spored and its hyphæ (and even the hairs) are always without clamps while the basidia of n. 119 are mostly 4-spored and its hyphæ are clamped. The absence of clamps in n. 118 is remarkable and may be correlated with its predominantly 2-spored basidia, thereby indicating the haploid state of its fruit body. This appears to be the first report of the absence of clamps in the genus *Ramariopsis* Donk emend.

## ACKNOWLEDGMENTS

The authors are deeply indebted to Mr. E. J. H. Corner, F.R.S., of the Botany School, University of Cambridge, England, for help in the identification of the species and valuable suggestions and Prof. P. N. Mehra, Head of the Panjab University Botany Department, for providing facilities and encouragement.

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## EXPLANATION OF PLATE

FIG. 1. *Ramaria flavobrunnescens* (Atk.) Corner, "Bright orange form", × ½ (approx.).

# OCCURRENCE OF *PHYSODERMA* SPECIES ON *MARSILEA MINUTA* L. IN INDIA

By S. Narayanaswami and N. S. Ranga Swamy
*Department of Botany, University of Delhi, Delhi (India)*

(Received for publication on November 13, 1956)

In the course of morphological studies on *Marsilea* we noticed a pathogenic fungus on the leaves and petioles of *M. minuta* in collections made from plants in the botanical garden of the University of Delhi. Infection appeared as numerous tiny, lenticular galls, yellow to deep reddish brown in colour. The petioles appeared twisted due to overgrowth of fungus galls on one side (Fig. 1). In some cases there was incomplete differentiation of the four leaflets. Gall-like excrescences were common on the sporocarps and in rare cases the latter were completely replaced by a gall-like swelling (Fig. 2).

Microscopic studies of the infected galls were made both by microtome sections as well as dissections. The morphology of the spore form indicated that the disease was incited by a *Physoderma* species which developed numerous intracellular resting spores. In the type of symptoms produced on the host, the disease closely resembled *Physoderma marsiliæ* described by Brewster (1952) from the United States of America on *Marsilea vestita*.

Rhizomycelium in the fixed material was not quite distinct and was observed only in few cases as a tenuous structure attached to the resting spores. Two to four resting spores were seen within the mesophyll cells especially the large ones bordering the ærenchyma (Fig. 3). Mature resting spores are ovate-ellipsoid, cinnamon yellow, flattened on one side indicating the position of the operculum, and measuring $18 \cdot 3–28 \cdot 3\,\mu \times 13 \cdot 3–25 \cdot 0\,\mu$. As the spores mature, the contents of the host cells become thick and deep yellowish-brown in colour imbedding the spores as in a matrix. Even in the mature state the spores are not released from the host cells and presumably germinate *in situ*.

As regards the identity of the fungus, comparisons were made with published accounts of *Physoderma marsiliæ* Brewster and *Synchytrium marsiliæ* Lodhi described by Ahmad and Lodhi (1953) on *Marsilea minuta* from Pakistan. In *P. marsiliæ*, Brewster described the occurrence of numerous folds or wrinkles extending to the lower one-third of the spore. Further, there were numerous antler-like haustorial processes in the young spores similar to those described by Thirumalachar (1949) in *P. limnanthemi* Thirum. These characters are absent in the present fungus in which the resting spores are smooth-walled with occasional rugose appearance due to the deposition of the granular contents of the host cell on the spore wall.


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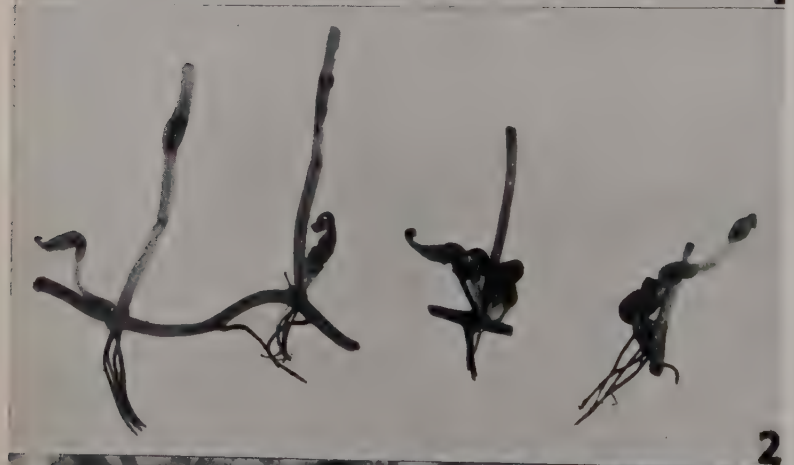
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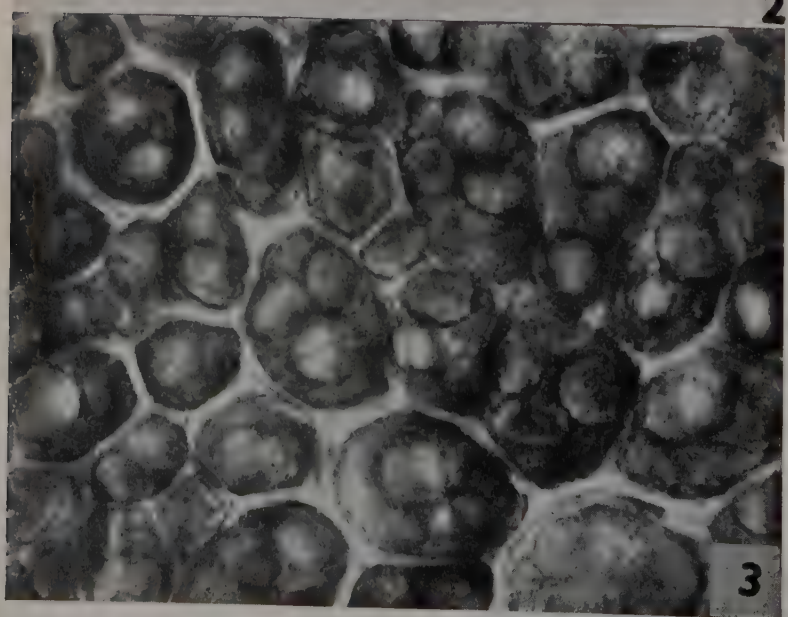
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Descriptions of *Synchytrium marsiliæ* indicate that it is identical with our *Physoderma* species and wrongly identified as a *Synchytrium* species. Since the type material of this fungus was not available for comparison, it was not possible to make a formal transfer of *S. marsiliæ* Lodhi to *Physoderma*. Further, the name *Physoderma marsiliæ* cannot be used again since the specific epithet has already been used by Brewster for a different species of *Physoderma* on *Marsilea vestita*. The exact identity of *Synchytrium marsiliæ* can be confirmed only at a future date when type material becomes available for comparison.

*Physoderma indica* Narayanaswami and Thirumalachar, M. J. sp. nov. Rhizomycelium indistinct, intracellular, tenuous. Resting spores 2–4 in each cell, yellowish brown, smooth measuring 18·3–28·3 $\mu$ long, 13·3—25·0 $\mu$ wide with a mean of 23·6 × 19·8 $\mu$. Germination not observed.

*Habitat*.—On leaves and petioles of *Marsilea minuta* L., 30th April 1956, leg. S. Narayanaswami and N. S. Ranga Swamy, Delhi, India (Type).

Rhizomycelium indistinctæ, intracellulares, tenui, 2–4 spores in quaque cellulæ, flavo-brunnea, levea, magnitudinis 18·3—28·3 $\mu$ × in medio 13·3—25·0 $\mu$.

Type deposited in the Herb. Crypt. Ind. Orient, New Delhi, India.

In conclusion the authors wish to express their grateful thanks to Prof. P. Maheshwari for encouragement and to Dr. M. J. Thirumalachar, Chief Mycologist, Hindustan Antibiotics Ltd., Pimpri, Poona, for suggestions and confirming the identification of the fungus.

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## Explanation of Plate V

Figs. 1–3. Fig. 1. Infected leaves and petioles showing galls (arrow mark), × ¾. Fig. 2. Portions of rhizome-bearing infected petioles and sporocarps, × ¾. Fig. 3. Resting spores in mesophyll cells, ×650.

# HISTOLOGY OF SOME DESERT GRASSES

By B. N. Mulay and S. K. Salujha

*Department of Botany Birla College of Science, Pilani (Rajasthan)*

(Received for publication on August 30, 1956)

## Introduction

Considering the diversity of forms in grasses and their distribution in varied climates, they have received scanty attention concerning their histology. Sabnis (1919-20) worked the anatomy of about twenty grasses. Mcpherson (1939) pointed out the presence of cortical air-spaces in root of *Zea mays*. Shields (1951) studied the involution mechanism in leaves of certain xeric grasses. The present paper deals with a comparative account of the histology of four desert grasses: *Cenchrus biflorus* Roxb., *Cenchrus prieuri* Kunth. (Paniceæ), *Saccharum munja* Roxb. (Andropogonæ) and *Cynodon dactylon* Pers. (Chlorideæ).

## Materials and Methods

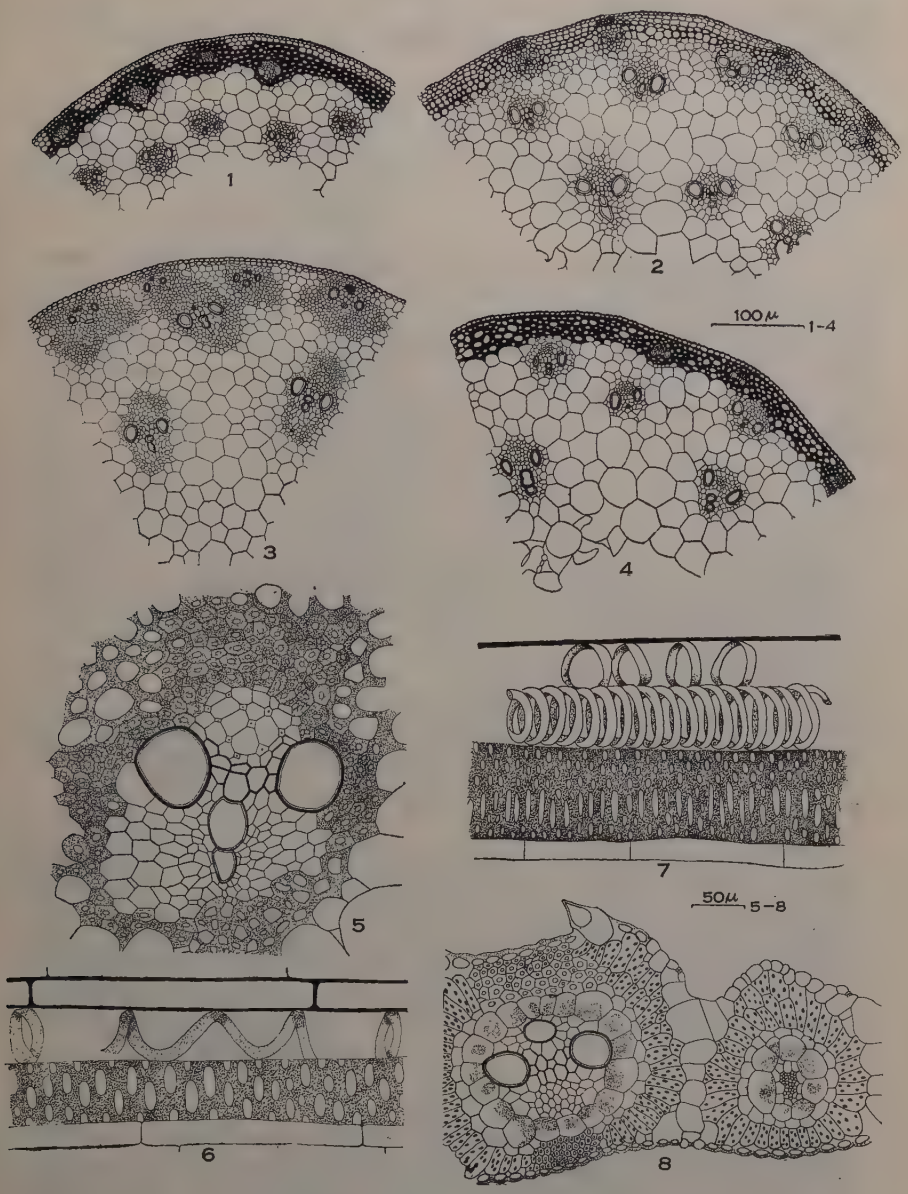
Materials of *Cenchrus biflorus*, *C. prieuri*, *Cynodon dactylon* and *Saccharum munja* were collected in the first week of August 1954, from places round about Vidya Vihar Colony, Pilani.

They were fixed in formalin-acetic-alcohol. Free-hand transverse and longitudinal sections of young and mature parts of roots and stems were taken. Microtome sections of leaves were made and stained with safranin—fast green. Difficulty was experienced in taking leaf sections due to deposition of silica. This was overcome by immersing them in 1% hydrofluoric acid for twenty-four hours.

## Observations

### *Stem*

In all the four species the epidermis is cutinised. Below the epidermis are the layers of parenchyma which are cut into patches by a ring of sclerenchyma below. This sclerenchymatous ring extends up to the epidermis in *Cenchrus biflorus*, *Cenchrus prieuri* and *Saccharum munja* (Figs. 1, 2 and 3), while in *Cynodon dactylon* the epidermis is immediately followed by three to five layers of sclerenchymatous tissue (Fig. 4). In the four species embedded in the peripheral sclerenchymatous layers area few undeveloped small, oval vascular bundles with reduced phloem. Protoxylem and its lacunæ are absent. Ground tissue consists mostly of angular and thin-walled parenchymatous cells in which are scattered larger vascular bundles. Each bundle is collateral and is surrounded by well marked sclerenchymatous sheath (Figs. 1, 2, 3 and 4). In *Saccharum munja* this bundle sheath is more developed over the phloem (Fig. 5). Protoxylem consists of spiral and annular vessels (Figs. 6 and 7). On the outer side of the xylem there are two large




FIGS. 1–8. Fig. 1. T.s. portion of stem of *Cenchrus prieuri* showing undeveloped and developed vascular bundles. Fig. 2. T.s. portion of stem of *Cenchrus biflorus*. Fig. 3. T.s. portion of stem of *Cynodon dactylon*. Fig. 4. T.s. portion of stem of *Saccharum munja*. Fig. 5. A vascular bundle of stem of *Saccharum munja* surrounded by well-developed sclerenchyma. Fig. 6. L.s. portion of stem

of *Cenchrus prieuri* showing annular, spiral and pitted vessels. Fig. 7. T.s. portion of stem of *Saccharum munja* showing annular, spiral and pitted vessels. Fig. 8. T.s. portion of leaf of *Cenchrus prieuri* showing ridges, furrows, bulliform cells and two types of vascular bundles.

pitted metaxylem vessels. The phloem forms an oval mass of tissue within the arms of the vessel and over the xylem. The central region consists of disorganised cells at the mature stage.

*Leaf*

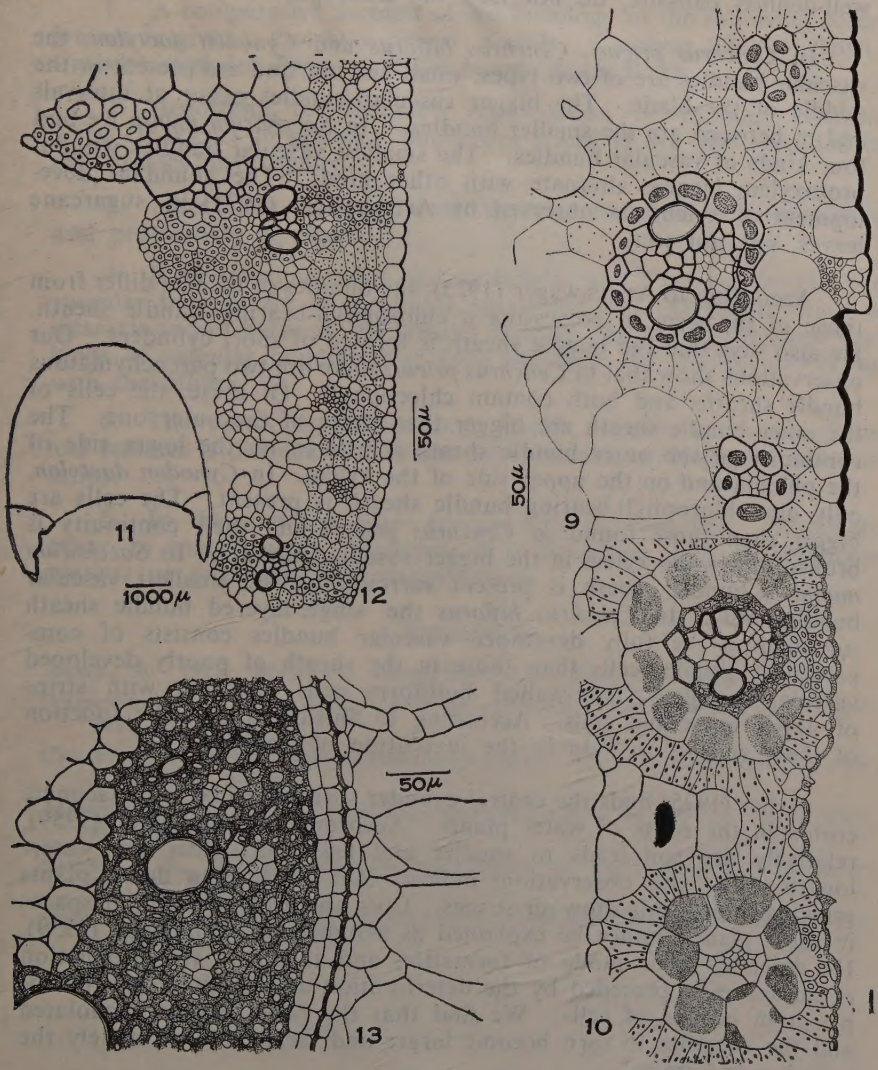
The upper surface of the leaf of *Cenchrus prieuri* and *Cenchrus biflorus* is ridged and furrowed (Figs. 8 and 9). Some cells of the upper epidermis project in the form of spine-like projections (Fig. 8). In the furrowed regions thin-walled bulliform cells (Figs. 8 and 9) are present. In *Cynodon dactylon* strips of upper epidermal cells alternate with bulliform cells (Fig. 10). Leaf of *Saccharum munja* is horse-shoe-shaped (Fig. 11). The bulliform cells are present at the two ends of lamina. Vascular bundles in the leaves of *Cenchrus prieuri*, *Cenchrus biflorus*, and *Cynodon dactylon* are of two kinds, and in *Saccharum munja* they are of four kinds. The bigger vascular bundles in comparison with smaller ones, have xylem and phloem quite distinct, with sclerenchyma on both the sides. The smaller vascular bundles possess feebly developed xylem and phloem elements. They are surrounded by bundle sheaths possessing chlorophyll. This bundle sheath in *Cenchrus prieuri* is double. It is broken on the lower side in the leaf of *Cynodon dactylon*. In *Saccharum munja*, sclerenchyma is more developed than in other species; another point of difference between this plant and the rest is the presence of a thin-walled sheath surrounding the smaller bundles only (Fig. 12). In the four species, stomata occur on the lower side.

*Root*

Next to the piliferous layer is the hypodermis, beneath which there are three to four layers of sclerenchyma. Internal to cortical sclerenchyma are cortical air-spaces which are prominent in all the species; they are comparatively larger in *Saccharum munja*. The air-spaces are delimited from the stelar region by well-developed endodermis (Fig. 13). Pericycle is more than one-layered. Pith consists of rounded thin-walled and loosely arranged cells, except in *Saccharum munja*, where it is sclerified.

## Discussion

Cheadle (1948) has divided the vascular bundles of monocots into six types. According to him Type IV only occurs in grasses. However, in the plants investigated Type I occurs in *Cynodon dactylon* and Type II in the stem and leaf of *Saccharum munja* in addition to Type IV. Cheadle (1948) has made no mention of the 'incomplete' vascular bundles in which protoxylem lacunæ are absent and phloem is only feebly represented. Such bundles occur at the periphery of the stem and leaf. Phloem is absent from the leaf bundles.




FIGS. 9–13. Fig. 9. T.s. portion of leaf of *Cenchrus biflorus* showing bulliform cells and vascular bundles. Fig. 10. Portion of leaf of *Cynodon dactylon* showing two types of vascular bundles. Fig. 11. Entire leaf of *Saccharum munja* in outline. Fig. 12. T.s. portion of leaf of *Saccharum munja* showing different types of vascular bundles. Fig. 13. T.s. portion of root of *Cynodon dactylon* showing air-spaces, endodermis, pericycle, phloem and xylem.

Arber (1925) suggests that the lack of anatomical differentiation into a palisade and spongy tissue in leaves may be correlated in some way with the chemical differences present in the leaves of monocots

and dicots. The leaves under observation, though not showing any well-defined palisade, do not lack the chlorophyll-containing tissue.

In *Cenchrus prieuri*, *Cenchrus biflorus* and *Cynodon dactylon*, the vascular bundles are of two types, small and big, and are present in the middle of the blade. The bigger vascular bundles occur at intervals and in between are the smaller bundles. In *Saccharum munja* we find four kinds of vascular bundles. The smallest vascular bundles without protoxylem lacunæ alternate with other kinds. The abundant development of xylem, as observed by Artschwager (1925) in sugarcane leaves, was not seen.

According to Artschwager (1925), the bundles of the leaf differ from those of the stem in possessing a chlorophyll-bearing bundle sheath. He also says that the bundle sheath is formed of short cylinders. Our observations show that in *Cenchrus prieuri* there are two parenchymatous bundle sheaths and both contain chlorophyll. Of these, the cells of the inner bundle sheath are bigger than those of the outer one. The continuity of the outer bundle sheath is broken on the lower side of the phloem and on the upper side of the xylem. In *Cynodon dactylon*, only one chlorophyll-bearing bundle sheath is present. The cells are bigger than those found in *Cenchrus prieuri* and their continuity is broken above the xylem in the bigger vascular bundles. In *Saccharum munja*, a bundle sheath is present surrounding the smallest vascular bundles only. In *Cenchrus biflorus* the single-layered bundle sheath surrounding the fully developed vascular bundles consists of comparatively smaller cells than those in the sheath of poorly developed vascular bundles. Thin-walled bulliform cells alternate with strips of upper epidermal cells. According to Shields (1951), the function of these cells is to help in the involution of leaves.

Arber (1925) finds the central cylinder surrounded by wide lacunate cortex in the roots of water plants. According to Mcpherson (1939), relatively dry soil leads to smaller and fewer air-spaces than water-logged soils. Our observations indicate that all the four desert plants growing in dry soils show air-spaces. Thus, the occurrence of air-spaces in these plants cannot be explained as assumed by Mcpherson (1939). He describes their mode of formation and says that the production of air-spaces is preceded by the deterioration and death of the protoplasm in groups of cells. We find that the cells become vacuolated and the vacuoles in turn become larger and larger and ultimately the cells become empty.

Endodermis in some cases in the secondary stages is rendered impermeable to water and solutes, by the presence of a suberin lamella on the inner surface of the cell-wall. When the cells of the endodermis suffer this change, a cork layer usually arises in the pericycle. In some roots under consideration a uniform thickening was found in the endodermal cells while in others passage cells were present. The pericycle cells are also sometimes thickened.

## Summary

1. A comparative account of the histology of the following desert grasses is given: *Cenchrus prieuri* Kunth., *Cenchrus biflorus* Roxb., *Cynodon dactylon* Pers., and *Saccharum munja* Roxb.

2. According to Cheadle's classification of vascular bundles, Type IV occurs in grasses; but Types I and II are also recorded in the grasses investigated.

3. Metaxylem in peripheral vascular bundles is ill-developed and protoxylem is absent.

4. In *Cenchrus prieuri*, *Cenchrus biflorus* and *Cynodon dactylon* the vascular bundles are of two kinds, small and big. The latter occur at intervals and in between the smaller bundles. In *Saccharum munja* four kinds of vascular bundles have been recorded, the smallest alternating with the others.

5. The chlorophyll-containing bundle sheath surrounding the leaf bundles is distinct. Bulliform cells alternate with upper epidermal strips.

6. In the root the outer cortical cells are sclerified. Air-spaces occur in inner cortex. Pericycle is 1–2-layered. Pith is parenchymatous or sometimes sclerenchymatous.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